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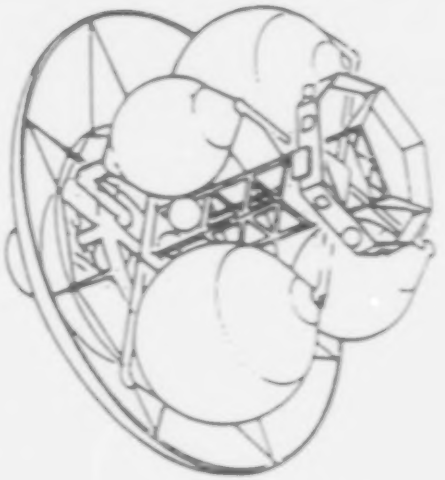
OTV Concept Definition And Evaluation - Mission And System Requirements

Volume II, Book 1

Orbital Transfer Vehicle Concept Definition And System Analysis Study

1985



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ORBITAL TRANSFER VEHICLE
CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY

VOLUME II
OTV CONCEPT DEFINITION AND EVALUATION
BOOK 1
MISSION AND SYSTEM REQUIREMENTS

July, 1986
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Prepared By: _____
Allen E. Kofal
System Analysis Manager

Approved By: _____
J. T. Keeley
Program Manager
Initial Phase

MARTIN MARIETTA
ASTRONAUTICS GROUP
P.O. BOX 179
DENVER, COLORADO 80201

FOREWORD

This final report, Volume III-System and Program Trades, was prepared by Martin Marietta Denver Aerospace for NASA/MSFC in accordance with contract NAS8-36108. The study was conducted under the direction of NASA OTV Study Manager, Mr. Donald R. Saxton, during the period from July 1984 to October 1985. This final report is one of nine documents arranged as follows:

Volume I	Executive Summary	
Volume II	OTV Concept Definition and Evaluation	
	Book 1	Mission and System Requirements
	Book 2	OTV Concept Definition
	Book 3	Subsystem Trade Studies
	Book 4	Operations
Volume III	System and Program Trades	
Volume IV	Space Station Accommodations	
Volume V	Work Breakdown Structure and Dictionary	
Volume VI	Cost Estimates	
Volume VII	Integrated Technology Development Plan	
Volume VIII	Environmental Analyses	
Volume IX	Study Extension Results	

The following personnel were key contributors during the July 1984 to October 1985 period in the identified disciplines:

Study Manager	J.T. Keeley (March 1985-October 1985) R.B. Demoret (July 1984-February 1985)
Project Managers	G.J. Dickman (Cryogenic Systems) A.E. Inman (Storable Systems)
Task Leads	J.H. Nelson (Missions, Trades & Programmatics) T.K. Stanker (Design) J.C. Mitchell (Operations) R.M. Randall (Accommodations)

Denver Engineering Support

Aerothermodynamics	G.W. Heckel
Avionics	R.B. Schroer, J.S. Schmidt
Flight Operations	L.A. Jenkins
GN&C Analyses	W.H. Willcockson
Ground Operations	J.S. Hostetler, C.D. Garner
Mission Analyses	S.G. Carson
Propulsion	E.C. Fox, T.J. Rudman, D.H. Beekman
Sp. Base Accommod.	D.L. Kelley, K.E. Faikner, N.E. Lefebvre
Systems Engineering	G.W. Mohrman

Michoud Engineering Support

Engineering Manager	W.P. Haese
Cost Analyses	R.A. Ernst, D.R. Callan
Ground Operations	C.D. Diloreto
Structural Analyses	G.S. Kovacevic, R. Pequet
Structural Design	J. Hamilton, F.W. Houte, C. Shanks, D. Stanley
Weight Analyses	C.A. Edmonson

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1.0 INTRODUCTION

1.1 PURPOSE

This document establishes the mission and system requirements for the concept definition and system analysis of the Orbital Transfer Vehicle (OTV). The requirements set forth herein constitute the single authority for the selection, evaluation and optimization of the technical performance and design of the OTV.

1.2 SCOPE

This requirements document shall form the basis for Ground and Space Based OTV concept definition analyses and establishes the physical, functional, performance and design relationships to STS, Space Station, OMV and payloads.

1.3 OTV MISSION OBJECTIVES

The objective of the OTV is to provide a flexible and efficient capability for satellite delivery, retrieval and servicing in the 1995 to 2010 time frame. The OTV will provide a capability to deliver and service large scale space systems/platforms operating in geostationary orbits or other high energy orbits as well as providing transportation for lunar and planetary missions. The OTV missions will include both manned and unmanned capabilities. An objective of the transfer vehicle is to operate in conjunction with the STS, Space Station and OMV in the performance of space operations.

1.4 SPACE STATION RELATIONSHIP

The OTV will evolve to a configuration that is based and operated from the Space Station. The OTV will be berthed, maintained and mission configured at the Space Station.

1.5 SPACE SHUTTLE RELATIONSHIP

The initial capability OTV will be ground based. The OTV will use the Space Transportation System (STS) for launch to Low Earth Orbit (LEO), for payload mating, and for mission deployment. After payload delivery, the OTV will return to the vicinity of the STS where it will be retrieved, prepared, and stowed in the Shuttle bay for return to earth.

The growth OTV will be space based. The STS will be used to transport the OTV to the Space Station for basing and to return the OTV to earth from the Space Station for ground maintenance or refurbishment.

1.6 OMV RELATIONSHIP

The Orbital Maneuvering Vehicle (OMV) will be used to ferry the OTV with or without a payload from the Space Station to a safe launch point. After releasing the OTV, the OMV will return to the Space Station.

The OMV will also be used to recover the OTV in the vicinity of the Space Station after a mission. The OMV will dock with OTV and bring the OTV, with or without a payload, to the Space Station for berthing.

The OTV shall operate in conjunction with OMV to provide a capability for:

a) Servicing, module changeout, or refueling of satellites and platforms operating in Geostationary Earth Orbit (GEO).
b) Retrieval/deorbit/relocation of space debris.
c) Retrieval of satellites.

2.0 APPLICABLE DOCUMENTS

The following documents of the exact issue shown, form a part of this specification to the extent specified herein.

In the event of conflict between documents referenced, and other detailed requirements of this specification, the contents of this specification shall be considered as superseding.

2.1 MSFC PROCEDURES AND HANDBOOKS

Document No.	Title
MSFC-HDBK-505A	Structural Strength Design and Verification Program Requirements

2.2 MSFC SPECIFICATIONS, REQUIREMENTS, AND REPORTS

Document No.	Title
MSFC 42A10210	Cable Assemblies and Wire Lists
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
MSFC-SPEC-1198	Screening Requirements for Nonstandard Electrical, Electronic and Electromechanical (EEE) Parts
ICD 80900000025	Final Report of ACC Study, OTV/dedicated ACC Interface, MSFC/P503
M&P-STD-EH13-1	Fracture Mechanics Analysis Requirements
OTV-86-001, May 1985 - June 1986	Revised Groundrules, OTV Concept Definition and System Analysis Study
OTV-86-002, 27 June 1986	Orbital Transfer Vehicle Mission Model, Revision 9, Space Transportation Systems Study Team Program Development, MSFC

2.3 MSFC-STANDARDS AND DRAWINGS

Document No.	Title
MSFC-STD-126E	Standard Inspection, Proof Testing, and Certification of Handling Equipment

MSFC-STD-506B	Materials and Process Control, Standard
MSFC-STD-512A	Man/System Design Requirements for Weightless Environments
MSFC-STD-526	Printed Circuit Boards, Plated through Holes
MSFC-STD-969	Standard Braze Filler Metal Control
MSFC-MA-001-006-2H	MSFC Software Management and Development Requirements
MSFC-42A10210	Cable Assemblies and Wire Lists

2.4 MILITARY STANDARDS AND SPECIFICATIONS

Document No.	Title
MIL-B-5087B	Bonding, Electrical and Lightning Protection, for Aerospace Systems
MIL-E-6051D	Electromagnetic Compatibility Requirements, Systems; Sept. 7, 1967
MIL-M-38310B	Mass Properties Control Requirements
MIL-STD-454	Workmanship
MIL-STD-461B	Electromagnetic Emission and Susceptability Requirements for Control of Electromagnetic Interference
MIL-HDBK-5B	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Plastics for Aerospace Vehicles
MIL-HDBK-23	Structural Sandwich Composites
MIL-STD-750	Particle Contamination Tests
MIL-STD-883	Test Methods and Procedures for Microelectronics
MIL-STD-975F	Standard Parts Lists for Flight and Mission Essential Ground Support Equipment
MIL-STD-1285	Marking of Electrical and Electronic Parts
MIL-HDBK-978 (NASA)	Parts Application Handbook
DoD-STD-686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding Electrically Initiated Explosive Devices)
DoD-STD-100	Engineering Drawing Practices
DoD-D-1000	Drawings, Engineering and Associated Lists

2.5 JSC DOCUMENTS

Document No.	Title
ICD 2-19001	Shuttle Orbiter/Cargo Standard Interfaces
JSC-07700, Vol XIV Sept. 86	Space Shuttle System Payload Accommodations
JSC-07700, Vol IX Sept. 82	Ground Systems and Operations Integration
JSC-07700, Vol XII	Space Shuttle Program Integrated Logistics Requirements
JSC-07700, Vol. XIV	Space Shuttle System Payload Accommodations
JSC-09095	Shuttle Systems Weight and Performance (Monthly)
JSC-10615	EVA Manual Description and Design Criteria
JSC-11123	Space Transportation Systems Payload Safety Guidelines Handbook
JSC-13830	Implementation Procedures for STS Payloads Systems Safety Requirements Payload Interface Verification
JSC-14046	Payload Interface Verification Requirements
JSC-14096	Training Annex Data Requirements
JSC-16741	STS/Payload Integration Guide
JSC-20001	Orbital Debris Environment for Space Station

2.6 NASA DOCUMENTS AND HANDBOOKS

Document No.	Title
NASA-TM-82478 (January 1983)	Space and Planetary Environment Criterial for Use in Space Vehicle Development
NASA-TM-86460	Natural Environment Design Criteria for Space Station
NASA-TM-82473 June 82	Terrestrial Environments (Climatic)
NASA-SP-8013	Space Meteoroid Environment
NASA-TP-2361	Design Guidelines for Assessing and Controlling Spacecraft Charging Effects
NHB-1700.1	NASA Safety Manual (Systems Safety)
NHB-1700.7A	Safety Policy and Requirements for Payloads Using the Shuttle Transportation System

NHB-5300.4 (1D-2)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program
NHB-5300.4 (3A-1)	Requirements for Soldering Electrical Connectors
NHB-6000.1C	Requirements for Packaging, Handling and Transportation for Aeronautical and Space Systems, Equipment and Associated Components
NHB 8060.1A	Flammability, Odor, and Offgasing Requirements and Test Procedures for Materials in Environments that Support Combustion

2.7 MSFC MANAGEMENT DOCUMENTS

MMI 1860.4B	Reporting Requirements for Minor Radioactive Sources, July 5, 1972
MMI 5310.2D	Alerts and Safe-Alerts, Reporting of NASA Parts, Materials and Safety Problems
MM 8040.12	MSFC Standard Contractor Configuration Management Requirements
MM 8040.13	MSFC Configuration Management Accounting and Reporting System
MMI 8040.15	MSFC Configuration Management Objectives, Policies and Responsibilities
MM 8040.5	MSFC Configuration Management Accounting and Reporting System
MM 8070.2F	Specifications and Standards, Approved Baseline List

2.8 KSC DOCUMENTS

Document No.	Title
KHB 1700.7A	Space Transportation System Payload Ground Safety Handbook
KMI 1710.1	Safety, Reliability, & Quality Assurance Program
STAR-027 Feb. 84	Shuttle Turnaround Assessment Report
K-STSM-14.1B Jan 83	Launch Site Accommodation Handbook

2.9 SPACE STATION DOCUMENTS

Document No.	Title
SS-SRD-500 February 11, 1986 (Initial)	Orbital Transfer Vehicle Accommodations System Requirements for Growth Station
SS-IRD-500 February 27, 1986 (Initial)	Space Station/Orbital Transfer Vehicle (OTV) Interface Requirements
SS-IRD-501 February 11, 1986 (Initial)	Orbital Transfer Vehicle Accommodations to Space Station Interface Requirements for Growth Station
SS-IRD-502 February 27, 1986 (Initial)	Orbital Transfer Vehicle (OTV) Accommmodations to Space Transportation System (STS) Interface Requirements for IOC Station
BJ-020117 November 18, 1985	MSFC Configuration Control Board Directive, Selection of the Dual Keel Power Tower Configuration as the Reference Space Station Configuration
JSC-19371 February 1985	Space Station Operations, Volume III, Proximity Operations

2.10 OTHER DOCUMENTS

Orbital Maneuvering Vehicle, Preliminary Definintion Study, Marshall Space Flight Center, revised January, 1985.

National Space Transportation and Support Study, Civil Needs, Volume I, Version 1.1, Final Report, Civil Need Working Group, 14 March 1986.

DoD Space Transportation Mission Requirements Definition, Space Transportation Plans and Architecture Directorate, Space Division, Air Force Systems Command, Aerospace Report TOR-0086 (6460-01)-1, 25 October 1985 as updated by Issue 3 (16 January 1986) and Issue 4 (6 February 1986).

Geostationary Platform Bus Study, Volume II, Draft Interim Report, Ford Aerospace, February 1986.

Geostationary Platform Bus Study, Volume II, Draft Interim Report, Lockheed, February 1986.

STS Propellant Scavenging Systems Study, Final Report, Contract NAS8-35614, Martin Marietta Michoud Division, Feb. 1985.

STS Propellant Scavenging Systems Study - Part II, Contract NAS8-35614, Martin Marietta Michoud Aerospace, Feb. 1986.

STS Propellant Scavenging Systems Study, Final Report STS-84-0570, Rockwell International Corp., Space Transportation Division, Jan. 1985.

STS Propellant Scavenging Systems Study, Final Report STS-86-0199, Rockwell International Corp., Space Transportation Systems Division, May 1986.

Tethered Satellite System (TSS) Interface Control Document, TSS-ICD-03, Martin Marietta Denver Aerospace, December 1984.

Tethered Satellite System Interface Requirements Document, TSS-IRD-03, Martin Marietta Denver Aerospace, June 1984.

Tethered Satellite System Payload Integration Plan Inputs, TSS-PIP-01, Martin Marietta Denver Aerospace, March 1984.

Tethered Satellite System Launch Operations Support Plan, TSS-LOSP-01, Martin Marietta Denver Aerospace, December 1984.

Tethered Satellite System Mission Operations Plan, TSS-MOP-01, Martin Marietta Denver Aerospace, February 1985.

Tethered Satellite System Mission Operations Requirement, TSS-MORD-01, Martin Marietta Denver Aerospace, February 1985.

Tethered Satellite System Desigr Reference Mission Document, TSS-DRM-01, Martin Marietta Denver Aerospace, June 1984.

3.0 SYSTEM REQUIREMENTS

3.1 General

This section defines design and performance requirements for (1) an initial ground based OTV and (2) an evolved growth Space Based OTV. Requirements for the Future Capability OTV encompass those requirements specified throughout this document for the initial OTV.

The OTV shall be a reusable vehicle (operating out of the STS and SS) with the basic capability of deploying and retrieving satellites to or from GEO. The OTV shall have the capability to perform the missions identified in paragraph 3.2, "OTV Design Reference Missions".

3.1.1 Control Philosophy

The control of the OTV will always be from a Ground Control Station. When within the SS control zone, the OTV will be safed and inactive. The OTV shall be capable of automatic flight.

3.1.2 Onorbit Repair/Maintenance

Extra Vehicular Activity (EVA) and remote operations shall be considered. The design shall accommodate replacement capability by both EVA and to the extent practical by automated or remotely controlled operations.

3.1.3 Design Life

The OTV shall be designed for 40 missions with maintenance. ORU's may be refurbished if shown to be cost effective.

3.1.4 Study Groundrules (Statement of Work)

The following ground rules and assumptions constitute requirements that shall govern the OTV concept definition.

a) Maximum utilization shall be made of applicable data and results from prior and current projects and government sponsored studies.

b) The potential utilization/commonality of systems/subsystems from existing and planned vehicles will be investigated for OTV.

c) The STS and future STS derivatives shall be considered as Earth launch vehicles and the Space Shuttle User's Handbook and Launch Site Accommodations Handbook for STS Payloads shall be used to provide guidelines. Definition of a baseline Aft Cargo Carrier for use in this study is defined by ICD 80900000025. Performance augmentation of the STS may also be assumed. NASA will provide definition of future STS augmentation and derivatives.

d) The early limited-capability Space Station will not have full provisions for OTVs. A growth Space Station will be operational in 1996, and it will be capable of providing full OTV fleet basing and servicing capability.

e) An Orbital Maneuvering Vehicle (OMV) will be available to support onorbit operations beginning in 1995. Definition of OMV will be provided by the MSFC Preliminary Definition Report.

f) All OTV configurations defined in this study shall evolve to become reusable and space based, but may have some expendable applications; shall incorporate aeroassist capability, and shall be capable of being evolved readily to space based manned vehicles.

g) Ground based OTV concept definition/assessment shall include consideration of operating in conjunction with Space Station.

h) On orbit operations analyses shall reflect cognizance of JSC Memorandum "Deployment of OTV/Payload from Aft Cargo Carrier" by K.M. Morrison, 24 November 1982.

i) Definition of payloads and payload operations will in general be limited in this Requirements Documents to the OTV mating and post-mating activities. Payload support at Space Station is specifically excluded. Remote OTV servicing concepts and the required support ancillary equipment will be defined. The definition of any required carrier for multiple payloads will also be included.

j) The mission model to be used for establishing requirements will be the latest revision of the NASA Space Transportation System Nominal Mission Model, which will include Space Station activities, and will be provided.

k) The contractor shall make maximum use of KSC ground operation experience.

l) The Shuttle Turnaround Analysis Report (STAR) will be used in the study for analysis of ground integration with STS and will be provided.

m) The OTV shall be capable of being deployed from the STS or Space Station to accomplish nominal transfer orbit burn at any true anomaly of any orbit. In addition to this, the OTV shall have sufficient consumables to provide backup transfer orbit burn opportunities on two consecutive orbital revolutions following the primary burn opportunity.

n) The OTV shall be capable of being captured and mated with an STS cargo bay carried payload using one or more RMSs and PIDA. EVA shall be used as a back-up for OTV mating to the payload. The OTV/payload shall be capable of being deployed on an improved RMS.

3.1.5 Evolution

Requirements which are to be met by an evolved growth version of the OTV will be identified separately from the requirements to be met by the original OTV.

3.2 OTV DESIGN REFERENCE MISSIONS

The OTV shall provide the capability to accomplish the Design Reference Missions (DRM) identified in this section.

The purpose of the design reference missions is to provide a baseline for OTV performance and mission operations. The DRMs shall be used as the basis for deriving performance requirements, determining mission durations, and, in conjunction with specified environments, forming the basis for subsystem designs.

Following deployment of the payload, the OTV shall perform an evasion maneuver followed by braking shaping burns to establish an aeromaneuver pass through the atmosphere which will result in the OTV being coplanar with the STS/Space Station and with a proper apogee for subsequent rendezvous.

3.2.1 Earth Orbital Payload Delivery

3.2.1.1 Multiple Payload Delivery

This DRM is Mission No. 18912 of the OTV preliminary mission model, Rev. 9.

The OTV shall be capable of delivering two, three, or four payloads in a single flight to a geostationary orbit. The aggregate delivery payload weight is 12,000 pounds and the return payload weight is 2000 pounds. The up payload is 15 feet in diameter and 35 feet in length. The down payload is 15 feet in diameter and 10 feet in length.

3.2.1.2 Geostationary Delivery

This DRM is Mission No. 18072 of the OTV preliminary mission model, Rev 9.

The OTV shall be capable of delivering a 15,000 pound payload to a geostationary orbit. The payload is 15 feet in diameter and 20 feet in length.

3.2.1.3 Geostationary Platform Low g Deployment

This DRM is Mission No. 13006 of the OTV preliminary mission model, Rev 9.

The OTV shall be capable of delivering a 14,550 pound operational geostationary platform payload to a geostationary orbit. The reference payload is 50 feet in length and 15 feet in Diameter.

In the performance of this delivery, the OTV shall not impart an acceleration greater than 0.1g on the payload.

3.2.1.4 Mid Inclination Delivery

This DRM is Mission No. 19036 of the OTV preliminary mission model, Rev. 9.

The OTV shall be capable of delivering a payload from the nominal STS orbit or the space station orbit to a mid inclination orbit which has a period of 12 hours. The OTV shall be capable of operationally accommodating geographic longitudes of the ascending node and right ascension of the ascending node throughout the range of 0 to 360 degrees. The performance requirements of this delivery mission shall be equivalent to delivering the following payload to a circular orbit of 19,300 nmi at an inclination of 63 degrees.

S/C: 10,000 lbs. equivalent, 15 ft. dia., 56 ft. in length

3.2.1.5 Low Altitude Mid Inclination Delivery

This DRM is mission No. 19037 of the OTV preliminary mission model, Rev. 9.

The OTV shall be capable of delivering a payload or payloads from the nominal STS orbit or the space station orbit to replenish a constellation of

satellites in circular orbits. The OTV shall be capable of placing the satellites in one or more inertial planes whose right ascension of the ascending nodes differ by multiples of 60 degrees. The performance requirements of this mission shall be equivalent to delivering the following payload to a 1000 nautical mile circular orbit at 63 degrees:

S/C: 110,000 lbs. equivalent, TBD dia., TBD ft. in length

3.2.2 GEO Shack Logistics

This DRM is Mission No. 15011 of OTV Preliminary Mission Model, Rev. 9.

The evolved growth OTV shall be capable of delivering a payload consisting of an OMV and servicer from the nominal STS orbit or the space station nominal orbit to a geostationary orbit at 0 degrees inclination. The delivery payload consists of:

Servicer: 12,000 lbs., 15 ft. in dia., and 15 ft. in length.

Upon reaching GEO the OTV shall deploy the Servicer within TBD nmi and TBD fps. of the satellite to be serviced. The OTV shall station keep at this position for TBD days. The Servicer shall rendezvous and dock with the OTV upon completion of the servicing. The OTV return payload consists of:

Servicer: 10,000 lbs., 15 ft. dia., 15 ft. in length

3.2.3 Earth Orbit Manned Servicing Mission

This DRM is Mission No. 15010 of the OTV Preliminary Mission Model, Rev. 9.

The evolved growth OTV shall be capable of delivering a manned payload from either the nominal STS orbit or the Space Station nominal orbit to a geostationary orbit at 0 degrees inclination. From this parking orbit, the OTV shall be capable of performing a rendezvous with the GEO Shack. The OTV payload shall have the following characteristics:

S/C: 12,000 lbs., 15 ft. in dia., 10 ft. in length

The OTV shall deliver the payload to a position where it can be docked to GEO Shack. The OTV will stay docked for a maximum of 20 days. While on orbit, the OTV shall provide a maximum of 800 fps delta velocity for the conduct of the mission. The return payload shall be manned and have the following characteristics:

S/C: 10,000 lbs., 15 ft. in dia., 10 ft. in length

3.2.4 Lunar Transport Mission

This DRM is Mission No. 17203 of the OTV Preliminary Mission Model, Rev 9.

The evolved growth OTV shall be capable of delivering a manned payload from the vicinity of the STS or the Space Station to a 60 nmi. circular orbit above the lunar surface at any inclination with respect to the lunar equator. The OTV delivery payload characteristics are:

S/C: 72680 lbs., 15 ft. dia., 32 ft. in length

The empty return mission shall occur during optimum time phasing with either the STS or Space Station orbital position. The maximum total mission time for this mission shall be 21 days.

3.2.5 Unmanned Injection Mission

This DRM is Mission No. 17088 of the OTV Preliminary Mission Model, Rev 9.

The evolved growth OTV shall be capable of delivering a comet sample return spacecraft plus associated expendable kick stage (EKS) from the vicinity of the STS or the Space Station into an intermediate orbit such that firing of the EKS will inject the spacecraft into an escape trajectory. The delivered payload characteristics are:

S/C: 20,000 lbs., 15 ft. dia., 25 ft. in length, C_3=45 km^2/sec^2

The OTV will be capable of performing TBD out-of-plane component brought on by the Space Station orbit being non-coplanar with the escape hyperbola.

3.3 GROUND BASED OTV

The ground based OTV shall be capable of being launched to LEO in the Shuttle Vehicle Aft Cargo Carrier and also in an Unmanned Cargo Launch Vehicle which may or may not have the capability to return the OTV to Earth after completion of the OTV mission. The OTV shall be designed to be returned to JEarth inthe Shuttle cargo bay.

3.3.1 STS Performance

The STS capability to BRM-1 for ground-based missions is 72,000 lbs. BRM-1 mission capability shall be adjusted for ground-based ACC/OTV missions to reflect the following changes in mission plan:

a) ACC delta fixed wt. (remains with E.T.) - 4000 lbs.
b) ACC shroud penalty - 2000 lbs.
c) ACC drag penalty - 200 lbs.
d) Payload ASE - 10% of payload weight
e) Chargeable weights for STS mission support:
   (1) PIDA - 300 lbs.
   (2) Crewmen - 432 lbs./man for more than 4 days
   (3) Crewday - 10 lbs./man for more than 7 days
   (4) EVA - standard capability is 2 EVAs - 2 crewmen; add 256 lbs; for more than 2 EMUs; add 1502 lbs. for 2 MMU/FSSs; add 10 lbs./crewman for expendables for more than 2 EVAs plus 7 lbs. for LiOH recharge and 10 lbs. for an extra battery.

3.3.2 Unmanned Cargo Launch Vehicle Performance

The Shuttle Derived Vehicle capability for delivering to the vicinity of the space station is 150,000 lbs. to a 160 nautical mile, 28.5 degree inclination orbit; the cargo bay is 25 feet by 90 feet. This vehicle may have the capability of returning the OTV and payloads (40K lbs. total weight) to Earth after completion of the OTV mission.

3.3.3 Aft Cargo Carrier Interfaces and Constraints

The ACC is baselined for OTV delivery to the STS circular orbit. The following data have been abstracted from ICD 80900000025.

3.3.3.1 General

The ACC mission scenario is shown in Figures 3.3.3.1-1 and 3.3.3.1-2.

The Space Shuttle Vehicle (SSV) sequence of events occur in a normal manner, including AFT Cargo Carrier (ACC) shroud jettison, until SSV main engine cutoff (MECO). Following MECO, the OTV is separated from the ACC prior to external tank separation and reentry. The OTV propulsion subsystem is activated and continues into park orbit under its own power. The OTV park orbit is such that the SSV can maneuver to close proximity to permit removal of the mission payload from the SSV cargo bay, and mating with the OTV. The OTV/payload mating operations are performed under control of the SSV crew within program constraints.

Following OTV/payload mating, the OTV proceeds through a sequence of events for the delivery of the payload to a prescribed orbit, and then deorbits in such manner that the vehicle passes through the earth's atmosphere thereby expending vehicle energy. Upon exiting the atmospheric pass, the OTV will circularize in a park orbit such that the SSV can rendezvous with and retrieve the OTV. The retrieval process and OTV vehicle safing will be under control of the SSV and program constraints. The OTV hardware returned to earth shall fit within the confines of the SSV payload bay.

3.3.3.2 Aft Cargo Carrier Coordinate Conventions

The standardized coordinate reference planes, data point origins and directional conventions established for the ET, are to be used for the ACC (Figure 3.3.3.2-1).

The forward designation is related to the direction of flight. The ET Y-reference plane intersects the ET (and attached orbiter) longitudinal centerlines. The Z-reference plane is parallel to the longitudinal centerlines of the ET and the attached SRBs, and is arbitrarily located 400 inches from the ET longitudinal centerline in a direction opposite the attached orbiter. The X-reference plane is normal to Y and Z planes and is arbitrarily located 2058 inches forward of the center of the two aft ET-to-orbiter structural attach points. Fore and aft distances along the longitudinal ET axis are designated ET "Stations", and are measured as positive (+) distances from the S-reference plane.

RIGHT and LEFT designations are in the +Y and -Y directions, respectively, coinciding with the orbiter pilot's right and left perspective when the ET is assembled to the orbiter. Angular measurements around the circumference of the ET (within an X plane) are referenced to 0 degrees in the +Z direction (toward the attached orbiter); positive angles are clockwise looking forward. Clockwise and counterclockwise used herein will always be in the forward looking perspective.

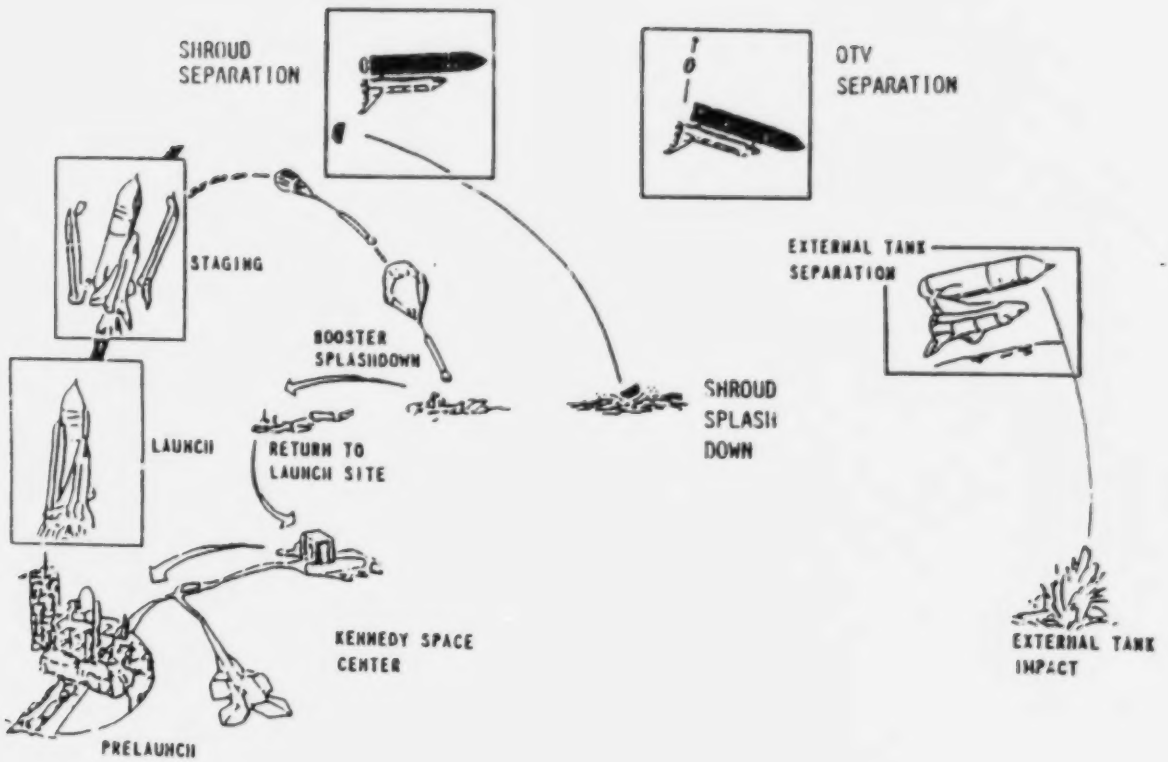

Figure 3.3.3.1-1 SPACE SHUTTLE ACC ASCENT PROFILE

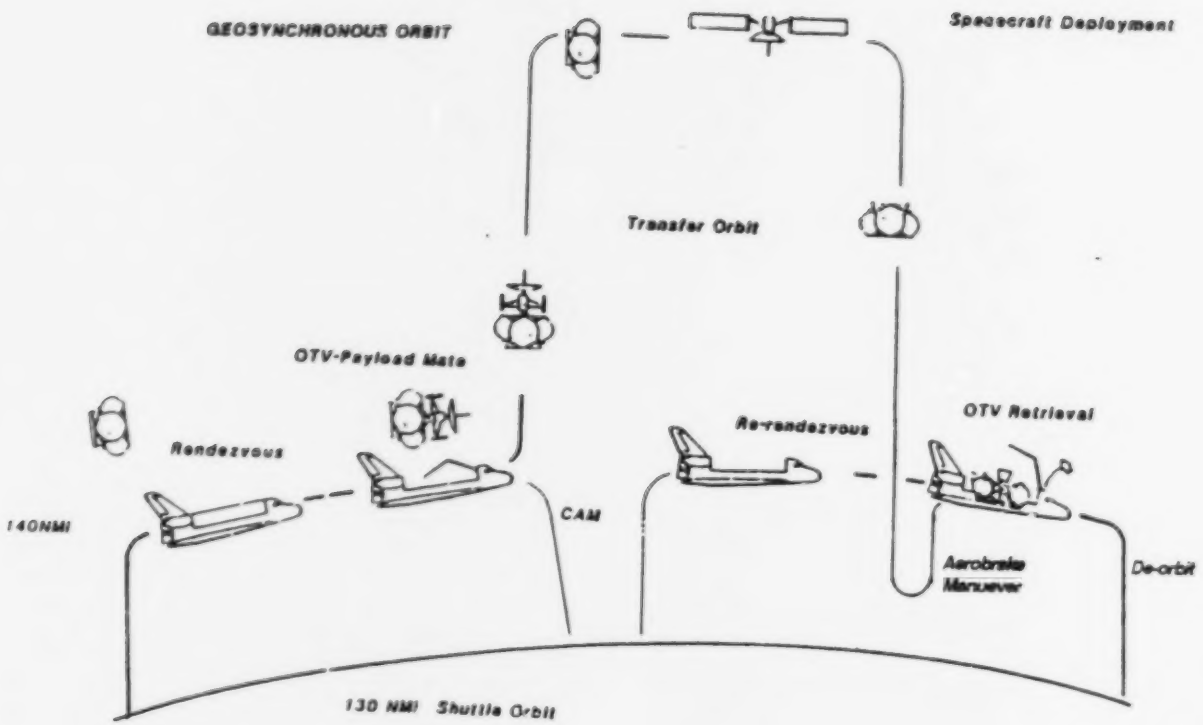

Figure 3.3.3.1-2 ACC OTV BASELINE MISSION

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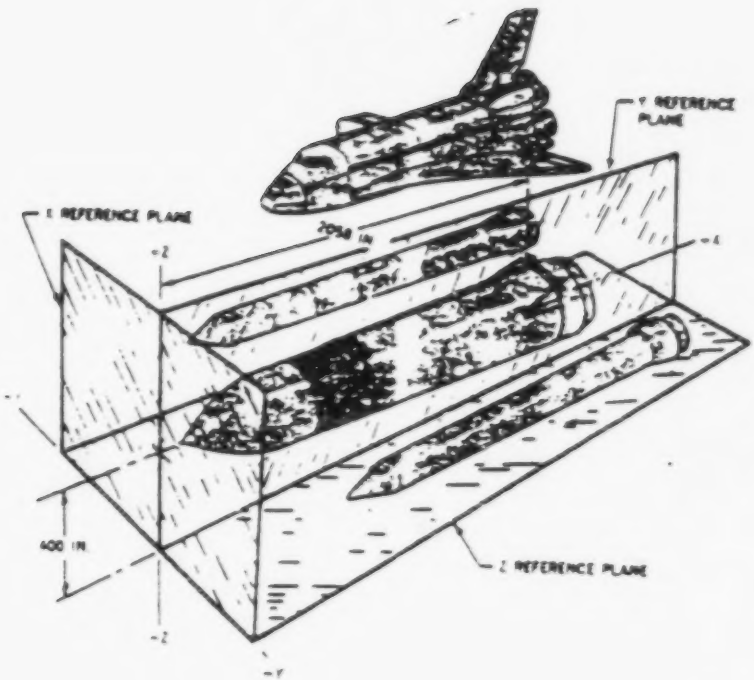

Figure 3.3.3.2-1 ACC COORDINATE CONVENTIONS

3.3.3.3 OTV/ACC Interfaces (General)

The controlled geometric relationship between the STS vehicle, the ACC and the OTV are shown in Figure 3.3.3.3-1 and alignment tolerances are shown in Figure 3.3.3.3-2.

The OTV shall not encroach upon the envelopes established in Figure 3.3.3.3-3. The limits apply to static and operational conditions from lift off through separation.

3.3.3.4 Functional Interfaces

The Orbiter shall provide the signal to initiate the command to separate the OTV from the ACC. The ACC shall have provisions for onpad contingency access to the OTV in the vertical attitude with doors to permit ingress and egress of personnel.

3.3.3.5 Interface Locations

The location of the four primary structural attachments and the positive directions for these attachments are shown in Figure 3.3.3.5-1. The fluid and electrical disconnects are located relative to AT-3 interface structural attach point (Figure 3.3.3.5-2). For details of these interfaces refer to ICD 80900000025.

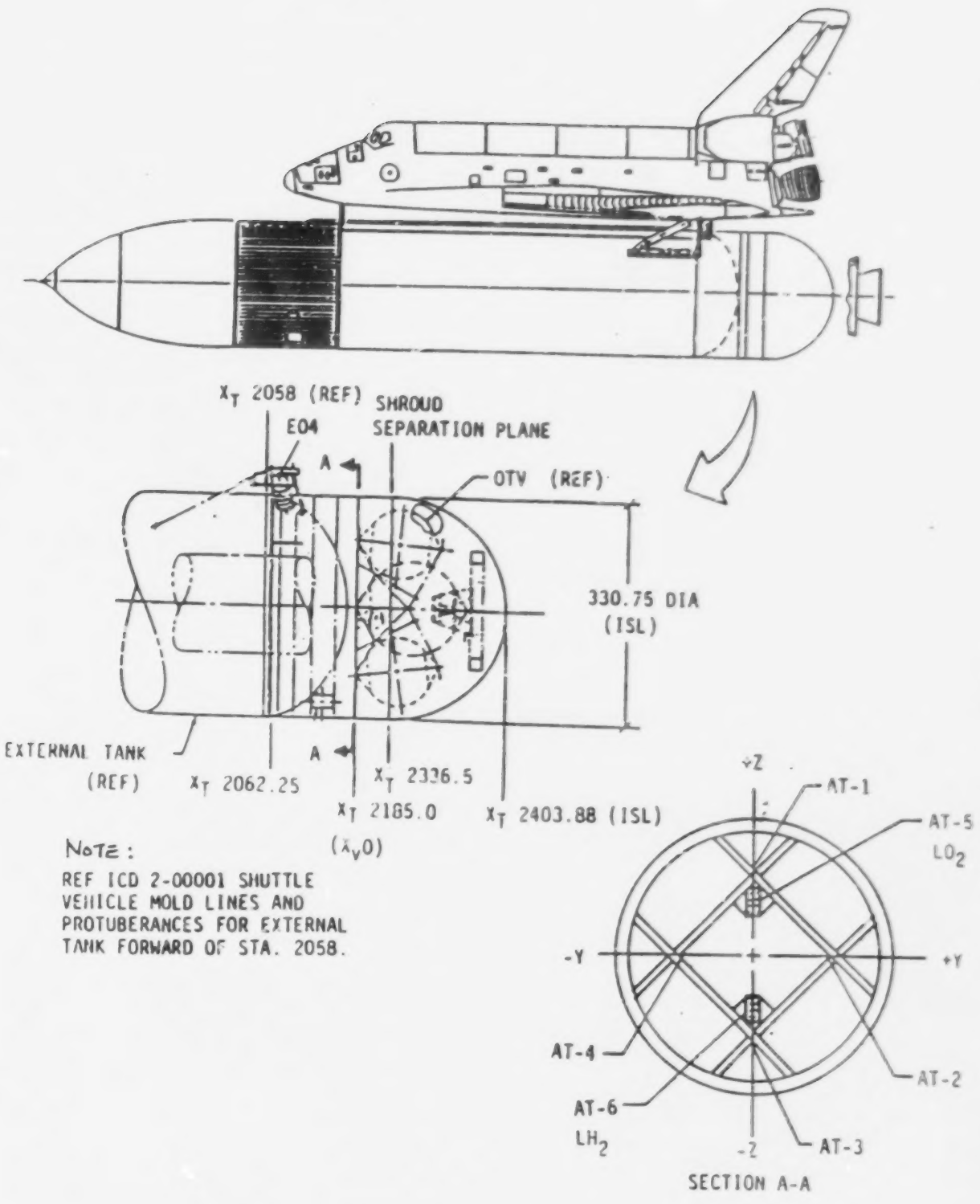

Figure 3.3.3.3-1 OTV/ACC INTERFACES (GENERAL)

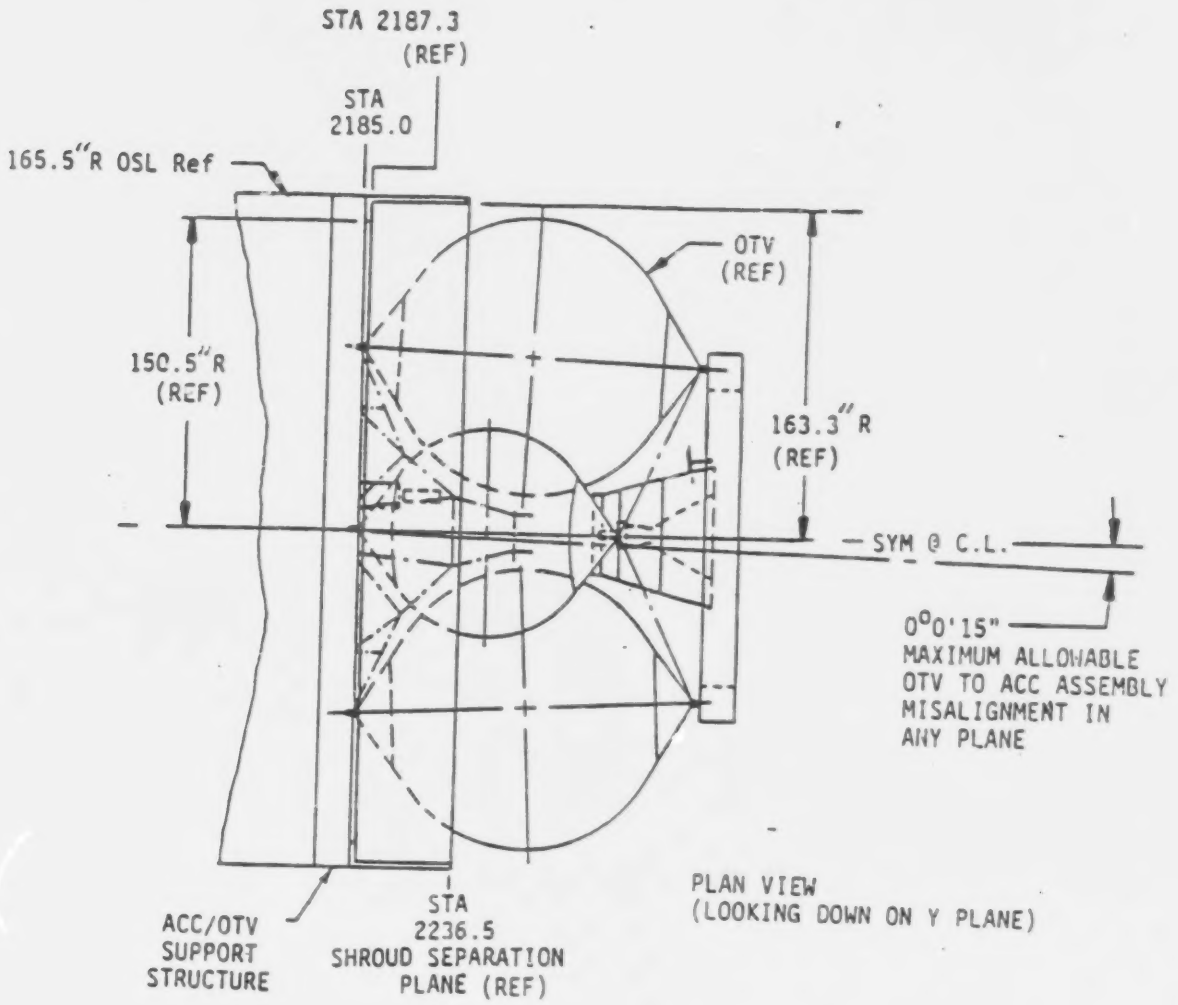

Figure 3.3.3.3-2 ACC/OTV ASSEMBLY ALIGNMENT TOLERANCE

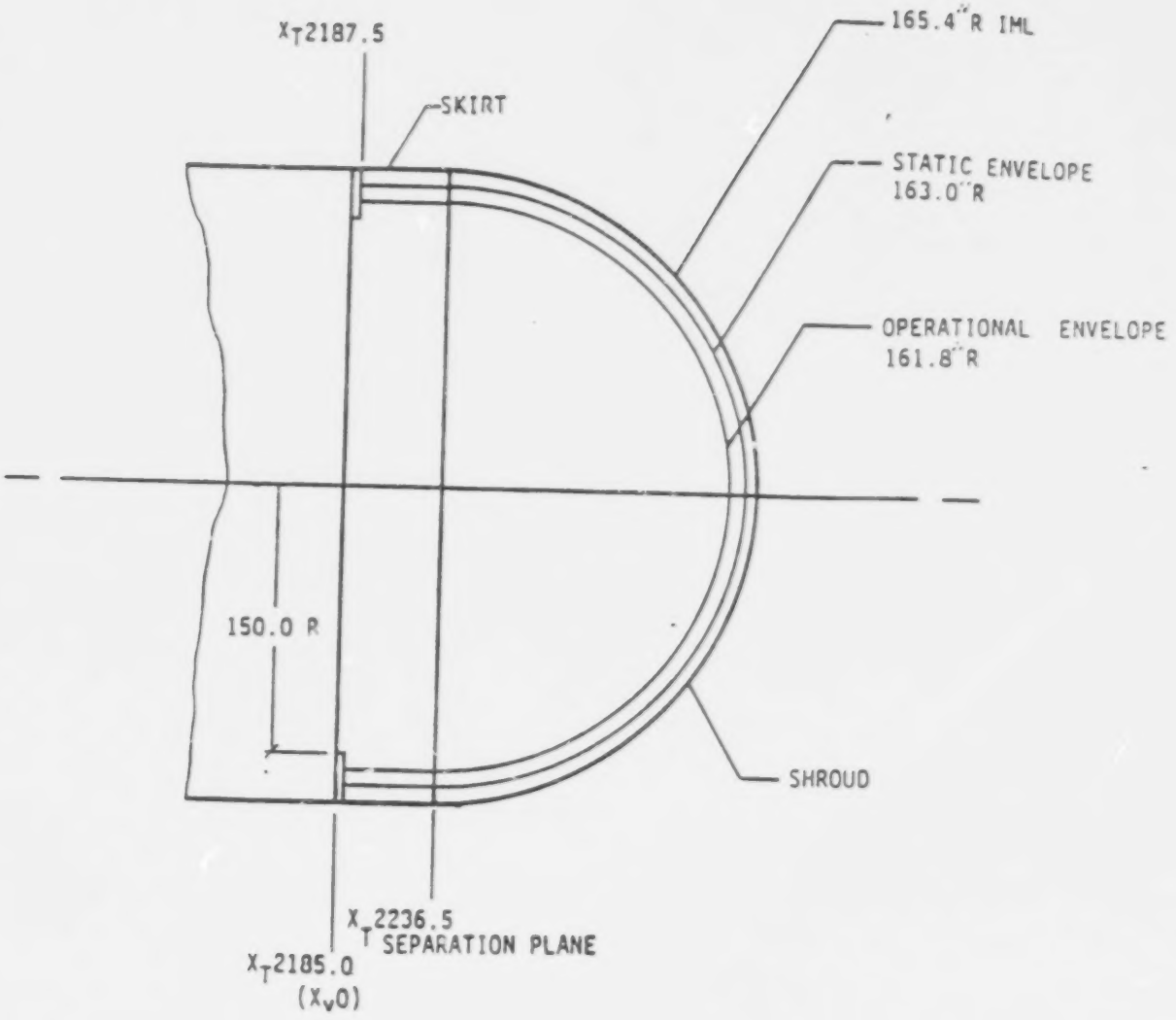

Figure 3.3.3.3-3 OTV STATIC AND OPERATIONAL ENVELOPE

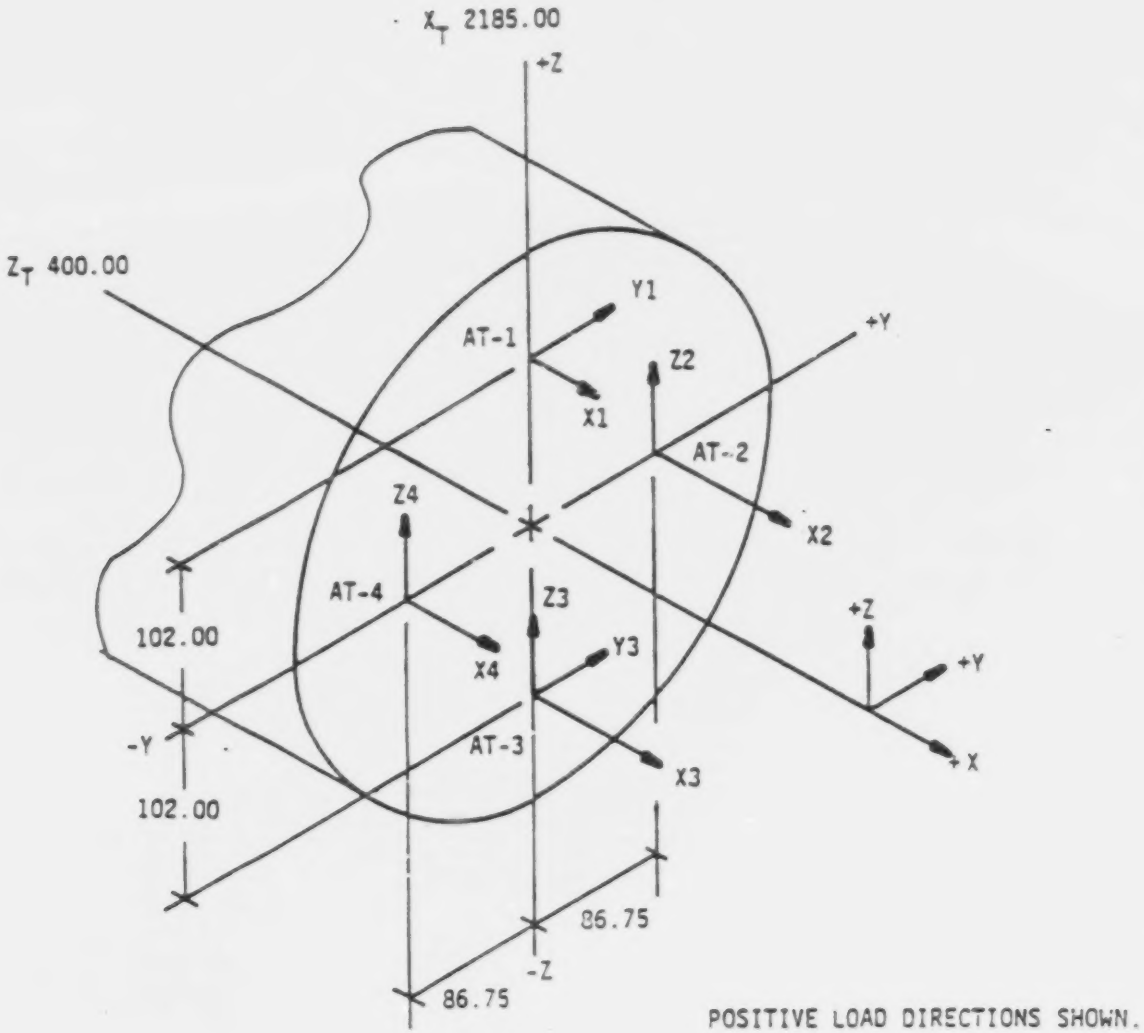

Figure 3.3.3.5-1 STRUCTURAL ATTACHMENT LOCATIONS AND OTV LOADS DIRECTIONS

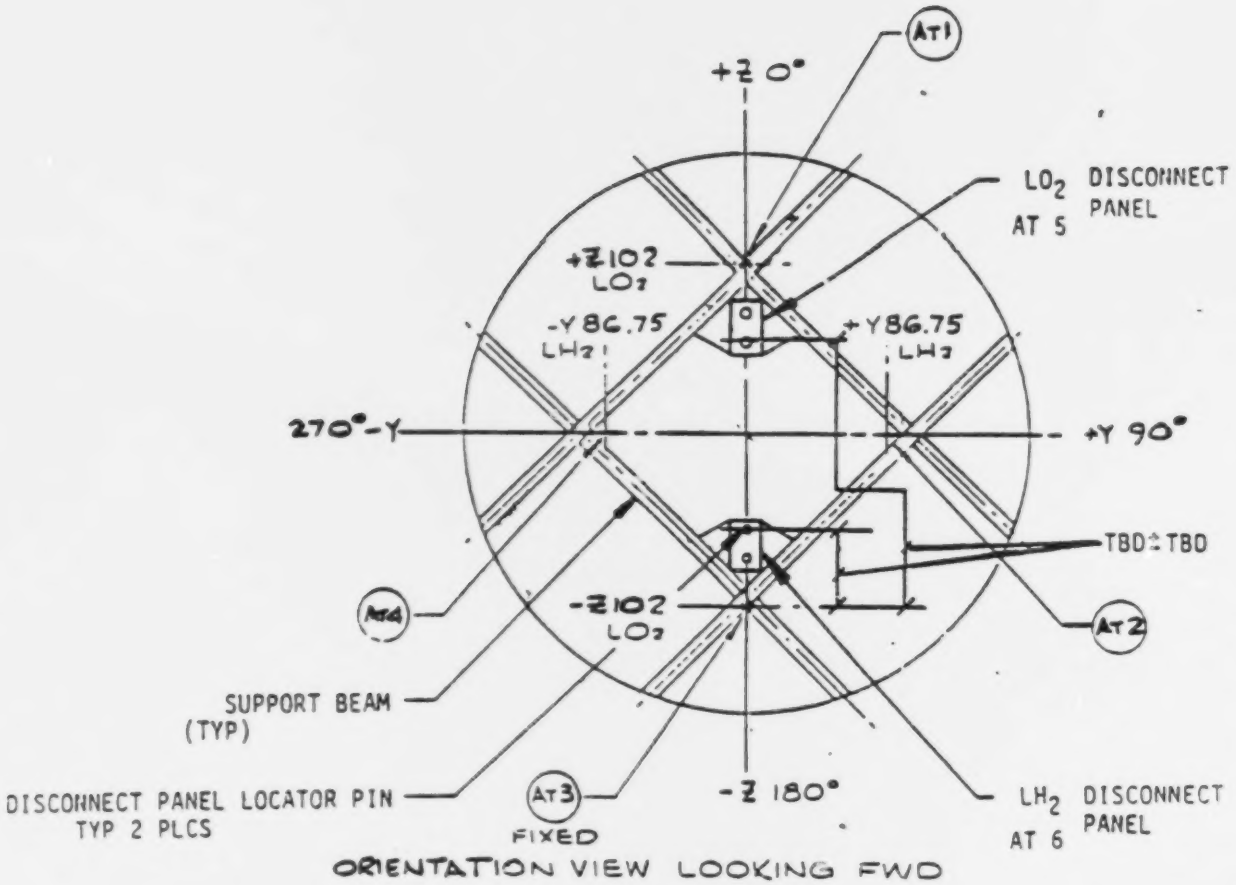

Figure 3.3.3.5-2 ACC/OTV FLUIDS AND ELECTRICAL UMBILICAL DISCONNECTS PANEL LOCATIONS

3.3.4 STS Interface Definition (Recovery)

3.3.4.1 Rendezvous and Recovery Operations

a) OTV proximity operations shall comply with Shuttle requirements for free flyers as delineated in JSC-7700, Volume XIV.

b) Final approach to the OTV shall normally commence from TBD feet at which point the OTV becomes sensitive to Orbiter RCS plume overpressure. From that point the Orbiter transfers to the final station keeping position (approximately 30 feet from the OTV) for capture. One of four basic final approach techniques may be used:

1) Direct Approach - Primary technique in previous U.S. Space programs, using relatively high closing velocities up to final braking.

2) V-Approach - A controlled approach is conducted along the payload velocity vector, with an initial closing rate of 1.0 fps. at 1000-foot range. Final braking may be performed by +Z or $\pm$X RCS.

3) R-Approach - Orbiter approach is made along the radius vector to the payload and utilizes orbital mechanics effects as a braking force. This technique minimizes RCS braking thereby reducing overpressure effects.

4) H-Approach - The final approach is made from an out-of-plane position on the payload momentum vector. The relatively large final braking delta-V should be primarily out-of-plane.

c) The OTV shall be capable of maintaining attitude and residual velocities during Orbiter retrieval to the following accuracies:
Longitudinal Velocity - $\pm$ TBD ft/sec
Lateral Velocity - $\pm$ TBD ft/sec
Angular Misalignment - $\pm$10 degrees
Angular Rate - 1.0 deg/sec

d) To preclude damage resulting from Orbiter or OTV dynamic interaction, OTV active attitude or translational control system shall be inhibited per NHB 1700.7A. Small cold gas reaction forces may be accommodated, if required for stationkeeping.

e) For long range tracking prior to Terminal Phase Initiation (TPI) Burn (19 nmi. to 250 nmi.), the OTV must be capable of being tracked by the Orbiter by either providing a transponder compatible with the Orbiter cooperative radar mode or by providing surface reflectivity characteristics sufficient to insure visibility to the Orbiter star tracker. Close-in tracking post TPI (19 nmi.) shall be provided by an effective radar cross section of 6.3 meter^2 minimum.

f) Visual aids for approach and stationkeeping will be required. For nighttime operations, Orbiter overhead flood lights coupled with the required payload markers, or OTV running lights may be used (Ref. JSC ICD-2-19001).

g) The OTV shall be equipped with a grapple fixture which is compatible with the Orbiter Remote Manipulator System (RMS) end effector. Either a Flight Releasable Grapple Fixture (FRGF) or a Rigidized Sensing Grapple Fixture (RSGF) may be used. Both grapple fixtures must be releasable by a suited crew member during an EVA. If more than one recovery attitude is possible, grapple fixture locations must be compatible.

h) Extravehicular Activity (EVA) as a contingency only operation, shall be developed using the capabilities, requirements, definitions and specifications set forth in JSC 10615. An EVA egress path into the cargo bay of 4 feet minimum length must be available adjacent to the airlock outside hatch.

3.3.4.2 OTV To STS Cargo Bay Interface

The OTV shall be compatible with STS interface requirements as specified in the Space Shuttle Systems Payload Accommodation Document, JSC-07700, Volume XIV and JSC ICD 2-19001.

3.3.4.2.1 Physical

a. STS provided standard interface provisions shall be used to the extent practical.

b. The OTV shall be capable of installation in multiple STS cargo bay active positions. Keel and sill fitting loads shall not exceed the loads specified in JSC-07700, Volume XIV.

c. The OTV shall provide a grapple fixture compatible with the RMS end effector. The grapple fixture shall be located on the OTV such as to be accessible by the RMS. The grapple fixture shall be EVA removable to assure release of the OTV in case of an RMS end-effector failure. The grapple fixture must be compatible with JSC ICD 2-19001.

d. The OTV shall provide optical, radar targets, and docking aids, required by the STS, for deployment, capture, and rendezvous operations.

e. The OTV shall interface with the standard STS payload cabling during ground and flight operations.

f. Remotely activated devices used on orbit in the cargo bay for transferring resources (power, propellants, etc.), shall accommodate manual (EVA) backup for mate/demate, should the device fail.

g. The OTV design shall accommodate requirements of MSFC-STD-512A and JSC-10615 EVA design requirements.

3.3.4.2.2 Functional

OTV deployment and retrieval shall be compatible with and performed from the STS. The OTV shall provide a telemetry interface to and a command interface from the STS.

3.3.5 Unmanned Cargo Launch Vehicle Interfaces

To be determined/developed.

3.3.6 Payload Interface and Support

The OTV shall be capable of providing the following services to the payload:

a) Thermal attitude and continuous roll, if required.
b) Specific deployment attitudes and null rates prior to deployment of payload.
c) Collision avoidance maneuver providing 3.5 fps. velocity.

The OTV is planned to be a flexible space asset with the capability of accommodating a wide range of payloads and missions. As such, a bounding set of interfaces and support services are required to minimize the need to "customize" detail design characteristics of the OTV. The following interface and support services shall be provided:

3.3.6.1 Structural

The OTV shall provide a standardized structural interface which allows attachment to and separation from payloads. This structural attachment shall include accommodation of mechanically docking with a payload in space as shown in Figure 3.3.5.1-1.

3.3.6.2 Aeroassist.

The OTV aerobrake design shall be capable of returning payloads from geostationary orbits or lunar orbits to the STS or Space Station nominal orbits as defined in paragraph 3.2.

3.3.6.3 Rendezvous and Docking

The OTV shall utilize an OMV to facilitate rendezvous and docking with a payload.

3.3.6.4 Payload Thermal Conditioning

The OTV shall be capable of providing the payload up to a 0.1 rpm roll rate during delivery and stationkeep modes for thermal control.

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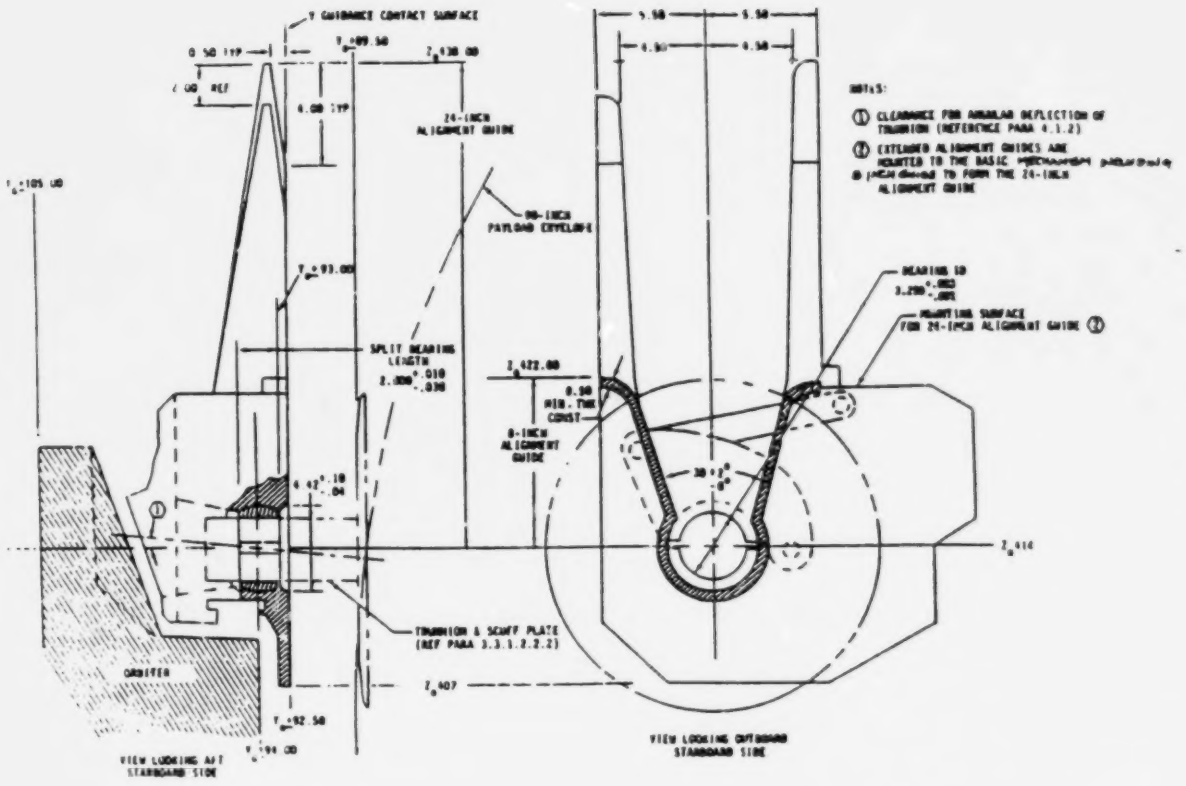
Y CLEARANCE CONTACT SURFACE
24-INCH ALIGNMENT GUIDE
90-INCH PAYLOAD ENVELOPE
SPLIT BEARING LENGTH
8-INCH ALIGNMENT GUIDE
TRUNNION & SCUFF PLATE (REF PARA 3.3.1.2.2.2)
ORBITER
VIEW LOOKING AFT STARBOARD SIDE
VIEW LOOKING OUTBOARD STARBOARD SIDE
NOTES:
① CLEARANCE FOR ANNULAR DEFLECTION OF TRUNNION (REFERENCE PARA 4.1.2)
② EXTENDED ALIGNMENT GUIDES ARE MOUNTED TO THE BASIC MECHANISM PALLET AT 8 INCH STEPS TO FORM THE 24-INCH ALIGNMENT GUIDE

Figure 3.3.5.1-1 ATTACH FITTING FOR DEPLOYABLE PAYLOADS

3.4 SPACE BASED OTV

The space based OTV will be designed for operations in conjunction with the Space Station where it will be assigned to delivery, maintenance and retrieval types of payload missions. The OTV design must be compatible with delivery to Space Station in the Space Shuttle payload bay if OTV assembly is to be completed at the Space Station or in the Aft Cargo Carrier where the OTV will be required to fly into a low earth orbit once deployed from the ACC. The space based OTV operations, like the ground based OTV operations, will use atmospheric drag to expend vehicle energy in order to return to the Space Station for reuse.

3.4.1 Space Station Operational and Support Constraints

The Space Station will provide a hangar for OTV stowage, servicing, payload integration, and pre and post mission servicing. The Space Station will also provide a cryogenic tank form with the capabilty of fueling and de-fueling an OTV. The tank farm may be co-located or remote from the Space Station.

3.4.1.1 Crew Support

The combined OTV operations scenario, from retrieval through launch, shall minimize Space Station crew involvement.

3.4.1.2 Power Consumption

Design of the OTV, supporting equipment and facilities, and operational scenarios shall be conducted so as to minimize the power consumption requirements placed upon the Space Station.

3.4.1.3 Mass Considerations

Design of the OTV, supporting equipment and facilities, and operational scenarios shall be conducted so as to minimize mass impacts upon the Space Station.

3.4.1.4 Ground Communications

OTV testing and checkout requirements shall minimize demands upon available Space Station ground communication links and crew involvement.

3.4.1.5 EVA/Automated Servicing and Maintenance

The OTV design shall emphasize servicing, resupply of its consumables and maintenance by automated means.

3.4.2 OMV Support to OTV

3.4.2.1 Launch

The fully loaded OTV with or without an attached payload shall be capable of being transported by the OMV from the OTV Space Station hangar to a safe separation distance in preparation for OTV launch.

3.4.2.2 Retrieval

A loaded OTV with an attached payload shall be capable of being transported from the retrieval standoff position to the propellant tank farm. The empty OTV, with or without attached payload, shall be capable of being transported by the OMV from the propellant tank farm to the Space Station hangar.

3.4.2.3 Propellant Resupply

The empty, or partially empty, OTV with or without attached payloads shall be capable of being transported from the OTV Space Station hangar to the propellant tank farm by the OMV if the propellant tank farm is separated from the Space Station. The fully loaded OTV and attached payloads (if so configured) shall be subsequently transported by the OMV from the propellant tank farm to the launch standoff position. The OTV shall be designed in a manner that allows evolution of the system to meet the more ambitious mission requirements with minimum impact and/or scar.

3.4.2.4 Propellant Detanking

A partially or fully loaded OTV with or without attached payloads shall be capable of being transported by the OMV from the retrieval standoff position to the propellant tank farm, and then subsequently transported empty, with the same attached payloads, from the propellant tank farm to the OTV Space Station hangar.

3.4.2.5 OMV Interfaces

The OTV shall provide a passive physical interface compatible with the OMV active physical interface to permit OMV transport of the OTV with or without attached payloads. Universal standard payload physical interfaces shall be compatible with the OMV passive physical interface to permit OTV transport of the OMV with or without attached payloads from a Space Station launch standoff position to an OMV servicing orbit position and return. Additionally, while at the OMV servicing orbit, these interfaces shall allow the OMV to demate from the OTV and, following subsequent servicing operations, remate with the OTV.

3.4.3 Returning OTV Orbit Envelopes

3.4.3.1 STS Envelope

The nominal OTV return aim point will be a 150 nmi circular orbit, 400 nmi ahead of the Orbiter. The return envelope is characterized by:

Altitude	$\pm$ TBD nmi.
Inclination	$\pm$ TBD nmi.
Down Range	$\pm$ TBD nmi.

3.4.3.2 Space Station Orbit Envelopes

The Space Station operations are confined to zones depicted in Figure 3.4.3.2-1 and described below. The Space Station rendezvous zone is zone 4.

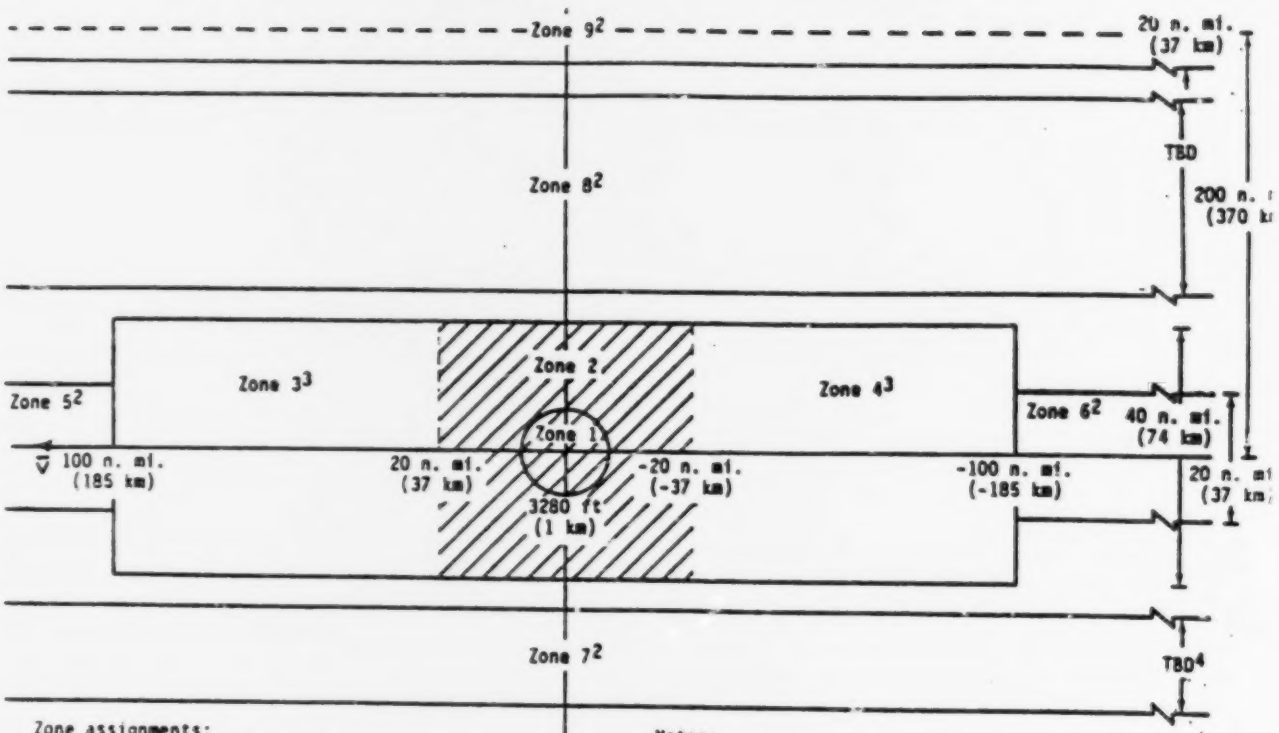

Figure 3.4.3.2-1 SPACE STATION OPERATIONAL CONTROL ZONES

ZONE 1 (TERMINAL ZONE)

Zone 1 consists of the region enclosed by an approximately 1 kmm(3280 ft.) diameter sphere centered about the Space Station. Within this zone, all proximity operations, including stationkeeping, fly-arounds, final approaches and berthing, will take place. In addition, nominal MMU and EVA activity will be performed within this zone.

ZONE 2 (CONTROL ZONE)

This concept assumes that the Space Station will have the capability to command and control any active unmanned vehicle when it reaches the boundary of the control zone.

This zone contains a slab-like volume of space that is curved and centered about the Station's orbit track. (Note that this shape is common to all zones centered around the Station's orbit). In the horizontal direction (curvilinear x), Zone 2 begins approximately 37 km. (20 nmi.) behind the Station and ends approximately 37 km. (20 nmi.) ahead of it. In the vertical direction (curvilinear z), the zone starts approximately 37 km. (20 nmi.) below the Station's orbit and ends approximately 37 km. (20 nmi.) above it. Finally, Zone 2 extends approximately $\pm$9 km. (5 nmi.) out of the Space Station's orbital plane (curvilineary).

In order to support its command and control responsibility, the Space Station is assumed to have two additional capabilities. It is assumed that these will only be utilized by the Station when an unmanned vehicle enters Zone 2. The functions are:

a. Monitoring - the Station should be capable of actively monitoring the system health portion of a vehicle's telemetry.
b. Tracking - the Station should be capable of actively tracking all unmanned vehicles within the control zone.

Limiting Station traffic control authority to Zone 2 provides two advantages. It reduces and defines antenna requirements and it frees valuable crew time that is better spent on things other than routine monitoring and flight planning and control.

ZONE 3 (DEPARTURE ZONE)

Most nominal departures from the space Station will take place within this zone after deployment and separation maneuvers are performed in Zone 1. This zone is centered upon the Station's flight path; it begins at the Station and extends forward to approximately 180 km. (100 nmi.). In the vertical dimension, it begins approximately 37 km. (20 nmi.) below, and ends approximately 37 km. (20 nmi.) above the Station's orbit track. This zone extends approximately $\pm$9 km. (5 nmi.) out of the Station's orbit plane.

Zone 3 has been located ahead of the Station to aid in contingency avoidance between departing vehicles and the Space Station.

ZONE 4 (RENDEZVOUS ZONE)

All nominal rendezvous with the Space Station will be targeted to arrive within this zone. Zone 4 is centered upon the Station's orbit track, and extends rearward from the Station to approximately 185 km. (100 nmi.). It is approximately 37 km. (20 nmi.) in the vertical dimension and approximately ±9 km. (5 nmi.) in the out-of-plane dimension.

This zone's location and size have been designed to be consistent with the standard stable orbit rendezvous technique in which the chaser vehicle arrives at an offset point some distance behind the target and performs its closing maneuvers from this point. Upon reaching Zone 1, the chaser will move from the rendezvous to the proximity operations mission phase.

ZONES 5 AND 6 (CO-ORBITING SATELLITE ZONES)

These two zones are dedicated to co-orbiting satellite operations. Zone 5 is the leading co-orbiting satellite zone. It begins approximately 185 km. (100 nmi.) ahead of the Space Station. It is centered around the Station's flight path and extends forward to the opposite side of the orbit; i.e., 180 degrees away from the Space Station (approximately 21,609 km. or 11,668 nmi.). Zone 6 is the trailing co-orbiting satellite zone. It begins approximately 185 km. (100 nmi.) behind the Station and follows the Station's orbit track until it contacts Zone 5. Hence, the co-orbiting satellite zones are continuous around the Earth.

ZONES 7 AND 8

These zones contain the non-coorbiting satellites. Zone 7 begins approximately 37 km. (20 nmi.) below the Station and extends downward to an altitude of approximately 185 km. (100 nmi.). Zone 8 begins approximately 37 km. (20 nmi.) above the Station. It extends to approximately 352 km. (190 nmi.) above the Station.

ZONE 9

This zone surrounds the parking orbit utilized by OTVs returning from geosynchronous or other high-energy orbits. It may also be used by spacecraft returning from lunar or planetary missions. Zone 9 is located 370 km. (20 nmi.) above the orbit track and has a radius of approximately 18 km. (10 nmi.).

3.5 OTV DESIGN

The OTV design shall be compatible with the payload delivery and retrieval missions described in Section 3.2. Payload integration with the OTV will occur either on the ground, in the STS park orbit, or at Space Station.

The OTV shall be capable of performing in accordance with the requirements of this specification after being exposed to the environments specified in section 3.7.

3.5.1 Performance Margins

Flight performance reserve (FPR) shall be equivalent to 2 % mission delta-V for each stage. FPR when carried in the topmost stage shall be RSS of individual stage requirements. A 10% margin on ACS consumption shall be carried.

3.5.2 Design Margins

Stage weight and engine performance shall reflect design conservatism as follows (imposed in worst direction):

a) 15% on dry weight of new subsystems and components; 5% on off-the-shelf items,
b) 1% on projected advanced engine performance,
c) 20% fuel cell reactant reserve,
d) Contractor shall use residuals (gas, fuel bias, mean outage) of 1% total propellant load for initial performance estimates and estimate actual performance for final configuration.

3.5.3 Reliability

All OTV systems critical to mission success shall be designed for autonomous checkout prior to deployment. Telemetry data stream, including vehicle health and status data, shall be transmitted to the available telemetry receiving systems during all critical mission functions.

3.5.4 Redundancy

Redundant paths, where applicable, shall be designed such that failure in one path shall not cause failure in another. This requires that such items as fluid lines, electrical wiring, connectors, etc., shall be located to the maximum extent to insure that an event which damages one will not damage the other. Redundant circuits and components shall be designed to preclude a single stimulus causing common circuit failures.

The OTV shall use "mirror image" redundancy as the means for implementation.

The design of all hardware systems incorporating redundancies shall include a means of verifying satisfactory operation of each redundant path.

3.5.5 Manrating

No single credible failure shall preclude the safe return of the crew to the Space Station or STS.

3.5.6 Subsystem Design Criteria

The OTV shall be capable of performing in accordance with the requirements of these criteria after being subjected to the natural and induced environments specified in Section 3.6 of this document.

3.5.6.1 Structural

3.5.6.1.1 Fatigue

Safe life design shall be adopted for all major load carrying structures. These structures shall be capable of surviving without failure a minimum of four times the total number of mission cycles expected in service (shown by analysis or by test through a rationally derived cyclic loading and temperature spectrum).

3.5.6.1.2 Design Factors of Safety

Design factors of safety defined in Table 3.5.5.1-1 shall be applied to OTV system, subsystem or component limit loads or pressures to obtain the design loads and pressures. Deviations from these factors will be allowed in those instances where sufficient data on loads and strength variations are provided to establish structural integrity on a probability basis. Requests for deviations with supporting data will be forwarded to NASA for approval prior to implementation. The design factors of safety shall be applied to loads derived from induced and natural environments, specified in Section 3.7. Unless otherwise noted, loads derived from off nominal conditions shall not require the factors defined in Table 3.5.5.1-1 applied for design purposed except for "one SSME out." Instead, off nominal loads shall be assessed against structural capability derived from nominal loads to determine the factor of safety that would exist should a failure occur. NASA shall be advised on a case by case basis whenever the factor of safety for failure modes is less than that specified for the nominal case.

3.5.6.1.3 Proof Tests

Proof testing of the OTV propellant tanks and pressure vessels will fulfill acceptance requirements of quality and maximum undetected flaw size in the tank.

3.5.6.1.4 Ultimate Factor of Safety Application

Ultimate factor of safety is 1.25 for well defined loads and 1.40 for other loads.

To obtain proof load or pressure, multiply the limit load (or pressure) by the proof factor. There shall be no detrimental yielding at proof load or proof pressure.

To determine proof factors for temperatures other than use temperature, use the following equation (fracture controlled component):

$$\underset{\text{(Test Temp)}}{\text{Proof Factor}} = \underset{\text{(Use Temp)}}{\text{Proof Factor FTR}}$$

When:

FTR = Fracture Toughness Ratio

$$\text{FTR} = \frac{\text{K of material at test temperature}}{\text{K of material at use temperature}}$$

When:

K = Fracture Toughness

General Structures	ULT.	YIELD	PROOF
o Well defined loads	1.25	1.1	No Proof Test
o Other loads	1.4	1.1	No Proof Test

Combinations of Pressure & Loads

- o When pressure loads and flight loads act in the same sense, Ultimate design load = Pressure x ultimate factor + flight loads x ultimate factor
- o When pressure loads relieve flight loads Ultimate design load = flight load x ultimate factor - pressure x limit load factor

Propulsion System	ULT.	YIELD	PROOF
o Limit Pressure	1.5	1.25	1.2
o Limit Load	1.4	1.10	

Lines Less Than 1.5 in Dia	ULT.	YIELD	PROOF
o Limit Pressure	4.0	2.0	2.0

Vessels, Actuating Cylinders, Valves, Filters and Switches			
o Limit Pressure	2.0	1.5	1.5

TABLE 3.5.5.1-1 FACTORS OF SAFETY

3.5.6.1.5 Combined Loads

The mechanical, external, thermally induced and internal pressure loads shall be combined in a rational manner according to the equations given in 3.5.6.1.4 to determine the design loads. In circumstances where certain loads (stresses) have a relieving, stabilizing or otherwise beneficial effect on structural load capability, the minimum expected value of such loads shall be used and shall not be multiplied by the factor of safety in calculating the design yield or ultimate load.

3.5.6.1.6 Ultimate Load

Ultimate load = safety factor x body loads - minimum expected pressure load. Any other loads induced in the structure, e.g., during manufacturing, shall be combined in a rational manner.

3.5.6.1.7 Allowable Mechanical Properties

The OTV shall be designed using the applicable allowable mechanical properties of MIL-HDBK-5, MIL-HDBK-17, MIL-HDBK-23, or NASA approved supplier guaranteed properties. Where values for mechanical properties of new materials or joints and where the properties of existing materials or joints in new environments are not available, they shall be determined analytically or by test. Where tests are required, they shall be of sufficient number to establish values for the mechanical properties on a statistical basis. The effects of temperatures, thermal cycling and gradients, and detrimental environments shall be accounted for in defining allowable mechanical properties. Material "A" (99 percent exceedance with 95 percent confidence) allowable values shall be used in all applications where failure of a single load path would result in loss of structural integrity.

3.5.6.1.8 Aeroelasticity

The OTV structure shall not experience deformation under limit loads that would limit performance of any functions.

3.5.6.1.9 Ground Handling Constraints

Major structural element design shall give consideration to, but shall not be constrained by, ground handling conditions. Design of local areas (fittings) will be defined by ground handling requirements.

3.5.6.1.10 Skin Panel Buckling

Skin panels supporting spray-on foam insulation (SOFI) and/or super light ablator (SLA) shall be designed to avoid skin buckling damage to the thermal protection system (TPS). The effect of support strength provided by the TPS is neglected in buckling analysis.

3.5.6.1.11 Stress Corrosion

The selection of materials used in the design of payload structures, support bracketry, and mounting hardware shall comply with the stress corrosion requirements of MSFC-SPEC-522.

3.5.6.1.12 Damage Resistance

The primary structure of the OTV shall be designed to be resistant to damage from external sources, including meteoroids and space debris.

3.5.6.1.13 Misalignment and Tolerances

The effects of structural misalignments and other permissible and expected tolerances shall be considered in the analysis of all loads, load distributions and structural adequacy. For establishing allowables, stresses and critical design stresses, the most critical combination of design tolerances shall be used.

3.5.6.1.14 Fracture Control

The OTV design for primary structure shall consider the presence of sharp cracks, crack-like flaws and other stress concentrations to prevent degrading the life of the structure due to sustained loads and cyclic loads coupled with environmental effects.

3.5.6.2 Aerobrake Subsystem Design Criteria

The ground based OTV aerobrake shall fit within the envelope of the ACC during ascent and be deployable prior to the aerobraking phase. The aeroassist system will be a low L/D, low ballistic coefficient concept. The brake shall provide wake heating protection to OTV components and exhibit aerocharacteristics compatible with flight control systems. The ground based brake shall be expendable or capable of being disassembled for return to earth in the STS cargo bay at the end of the mission for reuse. The life expectancy of the different types of aerobrakes is:

Fabric Ballute	1 mission
Fabric Lifting Brake	5 missions
Shaped Hard Shell Brake	20 missions

A ground-based aerobrake shall be designed to a factor of safety of four until aerodynamic loads are defined by the technology demonstration program and the OTV flight test program.

The space based aeroassist device shall be Space Station compatible and evolvable to manned missions. Space based designs will use a factor of safety determined by the experience gained in completing the aerobrake wind tunnel development testing and the ground based aerobrake flight experience. Both ground and space based aerobrakes shall be designed to maintain surface pressures and temperatures within structural limitations.

3.5.6.3 Propulsion

3.5.6.3.1 Main Propulsion

The main propulsion system shall provide the rocket engine(s) and propellant storage feed system to deliver the total impulse required for the OTV mission. The system shall be designed to meet the safety requirements of NHB 5300.4 (D-2) and operate safely in proximity to the Orbiter and Space Station in both manned and unmanned configurations. The Space Based OTV shall also be capable of being maintained on orbit by removal of modular components as required to prepare the OTV for subsequent missions. Detailed performance requirements are defined in Table 3.5.6.3.1.

Main Engine Performance Requirements	
Propellants	LO_2/LH_2
Propellant Mixture Ratio	6:1
Number of Engines	3
Thrust per Engine	5000 lbf
Specific Impulse	475 $\frac{\text{lbf - sec}}{\text{lbm}}$

Main Engine Operational Requirements	
Idle Mode	Tank Head and pumped
Throttle Capability	Step Down to PIM
Gimbal Angles	Up to $\pm 6°$
Number of Firings per Mission	5 to 10
Maximum, Minimum Times Between Firings	20 days, 20 minutes
Total System Lifetime	10 hrs Life, 300 Firings
Onorbit Refurbishment	ORU Entire Engine
Engine Burn During Aerobraking Manuevers	No
Engine-supplied Autogenous Pressurization	Yes

Table 3.5.6.3.1 - ADVANCED CRYOGENIC MAIN ENGINE REQUIREMENTS FOR GROUND AND SPACE BASED OTV'S

3.5.6.3.1.1 Rocket Engines

The OTV engines shall be capable of multiple starts and shutdowns and multiple thrust levels such as tank head idle, pumped idle and full thrust. The engines shall be reusable with a minimum of maintenance. The engines shall provide sensors to identify maintenance requirements to the extent that is practical. The engine shall be reusable after refurbishment and capable of supporting a 20 mission life. The engine system shall vector the main engines through the required thrust vector angles at the required rates.

3.5.6.3.1.2 Main Propulsion System Propellant Storage and Delivery System

The main propulsion system propellant storage and delivery system shall have the capability to load propellants into, and drain the propellants from, the OTV propellant tanks during prelaunch while the OTV is inside the Orbiter or the ACC and at the Space Station and tank farm if applicable. In flight the system shall be capable of gaging and delivering propellants to the OTV MPS engine at the flow rates and conditions required to maximize propellant utilization and satisfy engine thrust level. The system shall provide the capability of draining the residual propellants from the system and either inerting the system at the end of the mission prior to installing the OTV in the orbiter cargo bay for return to earth or reconfiguring the system prior to the next flight at the Space Station.

3.5.6.3.2 Reaction Control System

The function of the reaction control system (RCS) is to position and align the OTV in space, as required, to permit accomplishment of the following vehicle functions:

a) Manuevers
   1. Provide required thrust level and impulse bits on demand
   2. Provide on-orbit thermal control maneuvers
   3. Provide mid-course trajectory maneuvers
   4. Provide for separation from payloads
   5. Provide collision avoidance maneuvers

b) Orientation and Alignment
   1. Position OTV for rendezvous and pickup by the Orbiter RMS and Space Station MRMS
   2. Align OTV prior to main engine firing
   3. Provide roll control during main engine operations
   4. Align OTV for communication linkages

RCS performance requirements are defined in Table 3.5.6.3.2.

Reaction Control System Performance Requirements		
Propellants	-Ground Based	N_2H_4
	-Space Based	GO_4/GH_2
Propellant Mixture		4:1
Number of Thrusters		14
Thrust Per Thruster		100 lbf
Reaction Control System Operational Requirements		
Onorbit Refurbishment		Individual Thrusters

Table 3.5.6.3.2 - REACTION CONTROL SYSTEM REQUIREMENTS

3.5.6.4 Avionics

The avionics shall be a modular design capaole of functional and performance growth and reliability enhancement. It shall be compatible with the STS EM environment, especially regarding Ku-band radiation, as defined in JSC ICD 2-19001.

3.5.6.4.1 Guidance & Navigation (G & N)

The G & N subsystem shall determine inertial attitude, velocity and position, perform commanded attitude maneuvers, control velocity increments and provide outputs to vehicle control systems to be implemented to achieve the desired mission orbits.

The G & N system shall be designed to minimize velocity and position errors associated with the specified DRMs as well as satisfy G & N accuracy requirements for aerobraking. The design shall be capable of alignment and initialization on the pad (ground based) or onorbit (space based) and be capable of accepting in-flight attitude and state vector updates.

3.5.6.4.2 Attitude Control System (ACS)

The attitude control system shall provide 3-axis stable control of the vehicle about the guidance commanded attitude for all phases of powered and coasting flight. It shall respond to programmed guidance maneuver commands and be capable of being safed prior to retrieval. Control during + X-direction translation using the ACS thrusters shall be provided. The design shall incorporate a fine mode attitude control deadband for precise pointing and a propellant conservative deadband for long term limit cycle operation. Maximum thrust vector deflection shall not exceed 90% of available nozzle travel to provide control authority when considering worst case OTV and spacecraft CG offsets.

3.5.6.4.3 Data Management (DM)

The data management subsystem shall perform all data acquisition, formetting and computation functions required for the OTV. This capability shall include guidance, navigation and controls, telemetry formatting, command decoding, mission sequencing, redundancy management and checkout. Telemetry formats and sample rates shall be sufficient to allow fault isolation to the LRU level. Hardline telemetry data shall be provided to the Orbiter prior to deployment. The DM system shall interleave spacecraft, OMV or Manned module data into the OTV telemetry. Uplink commands can be routed through the OTV as a special service. The telemetry downlink shall include state vector, attitude and time data.

Timing and sizing margins at the beginning of Phase C/D shall be at least 100%. The DM system shall accept in-flight updates of specific operating registers as well as near complete memory reload. Software will be developed, verified, validated and managed using the guidelines of MSFC MA-001-006-2H. Maximum use shall be made of HOLs and modern programming and software engineering practices.

3.5.6.4.4 Mission Sequencing

OTV mission sequencing shall be autonomous but with override capability via RF uplink for contingency operations. The design shall satisfy NHB 1700.7A requirements for the number of serial electrical inhibits for critical ordinance and propulsion functions. Eight sequencing discretes plus backups shall be allocated to payload functions.

3.5.6.4.5 Communications and Tracking (C&T)

The OTV C & T system shall interface with the Orbiter, STDN and the TDRSS. Command and data links shall be compatible with the Orbiter payload interrogator when in range. Link margins to the Orbiter or the STDN shall not be less than 6 db. TDRSS shall be the primary mode of communication for LEO (below 12,000 km.) missions. Links to the TDRSS shall show a minimum margin of 3 db. The design shall not preclude hardware substitutional compatibility with the AFSCF (SGLS) for DoD missions, including encryption/decryption as necessary. Addition or substitution of DSN equipment for interplanetary missions shall also be available.

The C & T system shall accept uplink commands from the ground, the Orbiter or via TDRSS for real time safing or activation as well as retargeting and real time loading of state vector and GMT data. An interface with the GPS shall be provided to accept data for position and velocity determination.

3.5.6.4.6 Electrical Power Subsystem (EPS)

The EPS shall provide electrical power source switching and distribution for OTV functions. A single point ground philosophy isolated from structure, shall be followed. Power to the spacecraft, OMV or manned module shall be available as a kit only. Sizing of the energy source shall be compatible with the DRM times from deploy to deactivation for recovery.

The design shall allow mission completion with the loss of a single power source at any flight time. Non-critical functions shall be fused to preclude shorts that endanger mission success. The system shall accept and distribute electrical power from the STS (Reference Paragraph 3.3.1.2 of JSC ICD 2-19001 for STS supplied power levels), or the space station. Overload protection shall be provided.

3.5.6.4.7 Redundancy Management

Single point failure shall be minimized through the appropriate use of redundancy. Functions critical to mission success shall be single failure tolerant. Failure propagation shall be minimized through analysis and appropriate design.

The OTV shall be capable of detecting critical failures, isolating them to a redundant element and reconfiguring to bypass the failed unit with an operable element. This will be achieved through a combination of hardware redundancy and hardware/software fault isolation and reconfiguration (switching) capability. Redundancy management will be a combination of autonomous and ground controlled.

3.5.6.4.8 Checkout and Monitoring

A checkout and monitoring capability shall be provided for status monitoring and to support commanded checkout. Built in Test (BIT) shall be provided where possible to enhance status monitoring. Caution and warning data and monitors, if required, shall be available at the OTV electrical interface.

3.5.6.5 Thermal Control Subsystem

The OTV thermal control subsystem shall attenuate or control the environment of the OTV and of the payload/OMV if required during all potential environments encountered during the specified DRMs including aerobrake maneuvers. This shall include, as required, heat rejection from avionics/electrical components and thermal conditioning of propellants.

3.7 OTV ENVIRONMENTAL REQUIREMENTS

3.7.1 STS Environment

The OTV shall be designed to meet STS environments as specified in the most current edition of JSC-07700, Volume XIV, Section 4, and applicable sections of JSC ICD 2-19001.

3.7.2 Space Station Environment

The OTV shall be designed to meet the environment specified in TM-86460, Natural Environment Design Criteria for the Space Station Program Definition Phase.

3.7.3 Natural Environments

The OTV shall be designed to meet Terrestrial Environment (Climatic) criteria as specified in NASA TM 82473, and the Space and Planetary Environment criteria as specified in NASA TM 82478.

3.7.4 Spacecraft Charging

NASA TP 2361, "Design Guidelines for Assessing and Controlling Spacecraft Charging Effects," shall be utilized to ensure the OMV design is such that OTV spacecraft charging which may be detrimental to the OTV or vehicles to which it docks, will not occur.

3.7.5 Space Meteoroids and Debris

a) The space debris environment shall be based on the data in JSC 20001. Linear extrapolation from the Space Station altitude of 400 - 500 km to the shuttle orbit altitude of 200 - 300 km shall be utilized.

b) The meteoroid environment shall be as specified in NASA SP 8013.

3.8 LAUNCH PROCESSING

The OTV shall be capable of being launched from ELS or WLS on a Shuttle vehicle. The launch processing shall consist of OTV final assembly and checkout, vehicle and ASE integration with the SSV, verification of interfaces, propellant load and systems monitor. Note that for ACC launched OTV the payload integration does not occur during launch processing. OTV integration with the payload occurs in park orbit in the vicinity of the STS or the Space Station.

3.8.1 Ground Based OTVs

Ground-based OTVs shall be integrated into the dedicated Aft Cargo Carrier (ACC) which is attached to the External Tank at the Launch Site. OTV ground processing will consist of the activities required to receive and process for flight initial OTVs at the launch site, or OTVs returned from space operations via the Orbiter. Ground processing will encompass:

a) initial receiving inspection,
b) determination of maintenance requirements assembly,
c) maintenance and reconfiguration,
d) subsystem checkout,
e) OTV-to-satellite interface verification test, as applicable,
f) integration of the OTV with the ACC,
g) fueling, either offline or, in the case of the cryogenic OTV at the launch complex,
h) transfer to the launch complex,
i) integration with the ET and applicable Shuttle systems,
j) Launch.

The OTV design shall be compatible with existing Shuttle cargo ground processing capabilities, facilities and ground support equipment to the greatest extent possible in order to minimize program impact to the launch site. OTV design shall allow for reasonable access for late installation or removal of components or troubleshooting after integration of the ACC/OTV with the External Tank. The design shall consider requirements for safing/deintegration from the Shuttle payload bay in the Orbiter Processing Facility when the OTV is returned to the launch site for turnaround operations.

The ground-based OTV support equipment and procedures shall be driven by the need to transition to space based operations. The ultimate goal shall be to minimize turnaround time, personnel and equipment required for the ground based system in order to pre-validate space based concepts.

K-STSM-14.1B and the latest edition of STAR, and other applicable KSC data will be used as planning guides for ground processing analysis for launch operations.

3.8.2 Space Based OTVs

The space based OTV design shall be compatible with existing and planned launch site facilities, ground support equipment, and support services. Ground processing will involve initial OTV receipt, inspection, final assembly, system test, fueling as applicable, cargo-to-STS interface testing, if required, integration into the STS and launch.

As in the case of the ground based OTV K-STSM-14 and the latest edition of the STAR and other applicable KSC data will be used as planning guides for ground processing analysis for launch operations.

4.0 PHYSICAL CHARACTERISTICS

4.1 MASS PROPERTIES

Shall be documented and substantiated in accordance with the intent of MIL-M-38310B, Mass Properties Control Requirements, July 1, 1971. Any weight, center of gravity, moments of inertia, and/or principal axes constraints identified shall be reported. JSC 09095 shall be used as a guide for reporting weight.

5.0 RELIABILITY AND QUALITY ASSURANCE

5.1 SPACE SHUTTLE REQUIREMENTS

OTV Reliability and Quality Assurance requirements shall comply with the provisions of NHB 5300.4 (1D-2).

5.1.1 Criticality Categories

The following criticality categories supersede those in NHB 5300.4 (1D-2):

Category	Definition
1	Any single failure leading to loss of life or loss of STS vehicle or Space Station (SS).
1R	Redundant hardware element failures which could cause category 1 effect.
2	Any single failure leading directly to loss of OTV, OTV payload, STS mission or SS mission.
2R	Redundant failures which could cause category 2 effects.
3	All others.

5.1.2 Reliability Requirements

a. No two credible failures shall result in loss of life, STS or the SS.

b. No single credible failure shall produce a loss of STS or SS mission, loss of the OTV, or OTV payload.

c. The OTV shall have onboard failure detection, isolation and correction capability where necessary to avoid criticality 1 or 2 failure effects.

d. Combinations of systems failures shall be analyzed to insure compliance with paragraph 201 of NHB 1700.7A by the hazard analysis.

e. A program shall be established to meet the requirements of MMI 5310.2D, "Alerts or SAFE-Alerts, Reporting of NASA Parts, Materials and Safety Problems."

f. The OTV design shall assure a 0.999 probability of no meteoroid or space debris impacting propellant tank walls during all mission phases outside the STS or SS while in LEO awaiting STS rendezvous/retrieval the propellant tanks may be emptied. In this case there shall be a probability of TBD per week of no meteoroid or debris impacting propellant tank walls.

5.1.3 Failure Mode Effects Analysis (FMEA) and Critical Items List (CIL)

The OTV FMEA and CIL shall comply with NHB-5300.4 (1D-2).

6.0 MAINTAINABILITY

a. OTV maintainability requirements shall be implemented in accordance with NHB 5300.4 (1D-2).

b. The evolved growth OTV shall be maintainable at the SS.

c. For onorbit maintenance, the design shall accommodate EVA operations in accordance with JSC-10615, EVA Manual and MSFC-STD-512A man/system requirements for weightless environments. The goals for onorbit maintenance and servicing shall be to minimize EVA.

d. The OTV shall be serviceable, maintainable and repairable at ground facilities.

e. To the extent practicable, the OTV design shall permit access to components, ORU's and/or modules for either ground or onorbit removal and replacement.

f. ORU's shall be mounted to the OTV with self-aligning connectors and captive fasteners.

7.0 SAFETY

An OTV safety program shall be established and implemented in accordance with the requirements of this paragraph and NHB 1700.7A, "Safety Policy and Requirements for Payloads Using the National Space Transportation System." The safety program will be planned and developed in conjunction with other project activities. Applicable safety requirements and tasks shall be included in the basic management systems, design verification documentation, overall system analyses, and system engineering requirements, definition, and design review practices. The safety considerations shall be revised and updated as design and operational changes dictate.

Hazard analyses shall be performed to identify hazards and assure their resolution. Hazards which have been identified shall be classified in accordance with the hazard levels defined in NHB 1700.7A.

Any minor radioactive sources which will be launched into space as part of the OTV program shall be reported to NASA Project Management in compliance with MMI 1860.4B. If there are no radioactive sources to be launched into space with the OTV, a negative report will be required.

The OTV shall be designed to be compatible with rendezvous and retrieval requirements for the STS as defined in JSC-07700 Vol XIV specifically with regard to stabilization at grapple, visual ranging aids nighttime visibility and bump protection for berthing operations. Similar requirements will exist for rendezvous and berthing with the space station using the OMV.

The contractor shall be responsible for assuring that the OTV and its Ground Support Equipment (GSE) are safe. The OTV and GSE shall be designed to comply with the requirements of NASA Office of Space Flight document, NHB 1700.7A. To assess compliance with the safety requirements, four safety reviews for the payload, GSE, and ground operations safety will be conducted by the STS in accordance with JSC 13830. Payload reliability and quality is the sole responsibility of the payload supplier.

The Space Shuttle System will have dedicated safety equipment to insure the safety of the Orbiter and its flight crew. Safety design features include abort capability, caution and warning subsystem, vent provisions, and dry nitrogen inerting purge prior to launch. Specific safety equipment and capabilities aboard the Orbiter are TLD.

The OTV contractor shall be fully responsible to NASA for the following safety requirements:

a. The determination of the hazardous aspects of the OTV and the implementation of required corrective measures,

b. Assurance of the compatibility of the OTV with Space Shuttle System Interfaces,

c. Identification of residual hazards and interface incompatibilities prior to payload summary reviews and inspection.

Preflight summary reviews and inspections will be conducted to verify that NASA safety requirements have been met.

The specific safety requirements are contained in NHB 1700.7A. Launch site safety shall comply with KHB 1700.7, and KMI 1710.1. Ground Support Equipment shall comply with NHB 6000.1C, and MSFC-STD-126E.

8.0 DESIGN AND CONSTRUCTION STANDARDS

8.1 GENERAL

All flight vehicle hardware material and parts shall be procured to an approved materials specification and all parts shall be procured to an approved standard part drawing. Approved process specifications shall be used to control critical manufacturing and assembly operations.

8.2 Selection of Specifications, Standards and Processes

All materials, parts and processes shall be defined by standards, specifications and procedures selected from MM 8070.2F. Rationale for the selection of contractor specifications and standards over existing higher order of precedence staudards, specifications and procedures shall be submitted to MSFC for approval. The rationale shall include an identification of each higher-order-of precedence specification, standard or process examined and stated why each was unacceptable. For purposes of this order of precedence, commercial materials, parts and processes shall be considered equivalent to contractor standards.

The CEI's will contain a design and construction section, which details the specifications, standards and procedures to be used on the OTV project.

8.3 SPECIFIC SPECIFICAITONS, STANDARDS AND PROCFSSES

This section covers specifications, standards and processes not covered in MM 8070.2F.

8.3.1 Power Distribution Circuits-Overload Protection

Maximum operating temperatures for electrical power distribution circuit elements shall be established. Overload protection devices shall be designed, selected and calibrated to protect all elements of the circuit. The protection provided shall include considerations of wire and wire bundle derating factors that are necessary due to environmental conditions. Protection devices for branch circuits shall be designed so that the overloaded branch circuit will not be sufficient to allow upstream protection devices to act and remove power from other branch circuits of the system. Redundant power supplies shall be individually protected. Non-redundant power lines shall have remote circuit protection to provide at least one reset.

8.3.2 Protection from Improper Inputs

Electrical and electronic devices shall incorporate protection against reverse polarity and other improper electrical inputs during certification, acceptance, and checkout tests, if such inputs could damage the devices in a way that would not be immediately apparent. Such protection may be provided by ground-based equipment at the interface between a device and ground-test equipment.

8.3.3 Electronic, Electrical, and Electromechanical (EEF) Parts Requirements

8.3.3.1 Parts Program Plan

The contractor shall prepare, implement, and maintain a Parts Program Plan which describes in detail the parts program. This program shall comply with the requirements stated herein.

8.3.3.2 EEE Parts Selection

Maximum use shall be made of NASA standard parts, grade 2 minimum (including X-ray and PIND test as specified herein), in the design, modification, and fabrication of the flight equipment. The parts, selection, and screening shall conform to the requirements and guidelines contained in MIL-STD-975, NASA Standard for Electrical, Electronic, and Electromechanical Parts List, except that rescreening of JANTXV devices is not required. The program objective shall be to minimize part types, utilize standard part types to the maximum extent possible, and assure that appropriate minimum quality levels are maintained.

8.3.3.3 Nonstandard EEE Parts

Nonstandard parts (not listed in MIL-STD-975) may be used when there is no standard part with a performance capability to satisfy the application requirements or a standard part is not available. The minimum screening requirements shall be as specified in MSFC-SPEC-1198, "Screening Requirements for Nonstandard Electrical, Electronic and Electromechanical (EEE) Parts."

8.3.3.3.1 Nonstandard Parts Selection Criteria

Nonstandard parts shall be selected per Appendix X of MSFC-SPEC-1198. In addition, first consideration shall be given to the inherent capability of the parts to withstand the space, terrestrial, and mission environments to which the parts will be subjected.

8.3.3.3.2 Nonstandard Parts Approval Request (NSPAR)

A Nonstandard Parts Approval Request shall be submitted for each nonstandard part used in flight components. The rationale for use shall be included. NSPARs must be approved before procurement is allowed.

8.3.3.4 Particle Impact Noise Detection (PIND)

All cavity devices shall be PIND tested per Method 2020 of MIL-STD-883 (Microcircuits) and Method 2076 of MIL-STD-750 (semiconductors).

8.3.3.5 Radiographic Inspection

All cavity devices shall undergo Radiographic Inspection per Method 2012 of MIL-STD-883 (microcircuits) and Method 2076 of MIL-STD-750 (Semiconductors).

8.3.3.6 Destructive Physical Analysis (DPA)

All microcircuits and semiconductors (except non-cavity diodes) when procured to Vendor 883 or JANTX shall be subjected to DPA on a sample basis from each lot.

8.3.3.7 Parts Qualification

All EEE parts shall be qualified to the part level and to the application. The part shall be procured only from manufacturers that are qualified or their authorized distributors. Nonstandard parts shall be qualified by one of the following methods:

a. Qualification based on existing data that is applicable to the part design and manufacturer to be used in this project.

b. Qualification based on similarity, provided the design is similar, manufactured by the same manufacturer and processes, and the design differences are not great enough to invalidate the data.

c. Qualification through higher level of assembly testing for parts with previous space flight history only.

d. Parts of unusual design, materials, or construction techniques shall be qualified by complete part level qualification test.

8.3.3.8 Approved EEE Parts Engineering List

An approved EEE Parts Engineering List shall be maintained. This list shall include all NASA standard parts and all approved non-standard parts that are used in the equipment. This list shall be divided into flight and GSE component sections.

8.3.3.9 Derating Criteria

The EEE parts derating shall comply with the derating criteria of MIL-STD-975.

8.3.3.10 Flight Components Traceability

A traceability record which provides the following as-built information for each EEE part installed shall be prepared for each flight component:

a. Name of component(s) used in

b. Part number and circuit location (R_1.C_4, Q_2)

c. Manufacturer

d. Date code or lot number

e. Serial number when so marked

8.3.3.11 Other Requirements

The EEE parts shall also be controlled by MIL-STD-1285, DoD-STD-686, and NHB 1700.7A.

8.3.4 Cleaning

Plated through-holes shall be in accordance with MSFC-STD-526. Ultrasonic vibration shall not be used as a method for cleaning electronic assemblies.

8.3.5 Wire Splicing

Splicing wires of flight hardware shall be minimized. Any wire splicing must be approved by the OTV Project Office.

8.3.6 Cable Assemblies and Wire Lists

Cable assemblies and wire lists shall conform to MSFC 42A10210.

8.3.7 Castings

Castings shall not be used in the OTV design without specific MSFC approval.

8.3.8 Workmanship

Workmanship shall be in accordance with MIL-STD-454 and 5300.4 (3A-1).

Consideration for EVA in the STS bay with OTV must be considered. Workmanship, sharp corners, etc., must be in accordance with JSC-10615, EVA Manual.

8.3.9 Electromagnetic Compatibility (EMC) Requirements

a. The OTV shall be designed to be electromagnetically compatible within itself and with other interfacing systems. It shall meet the requirement of MIL-E-6051D (1) including preparation of an EMC Control Plan by the developer.

b. The equipment or subsystem shall meet the requirements of MIL-STD-461B, as modified to better fit the program requirements and to be compatible with special requirements of interfacing systems, such as the STS, SS, and payloads.

c. A single-point ground system shall be used such that power, signal and control circuits will not be returned through structure except for RF signals carried on coaxial cables. Wherever possible, circuit return shall be twisted with the outgoing side.

d. OTV structure and equipment and equipment mounting shall be electrically bonded in accordance with MIL-B-5087B.

8.3.10 Structural Strength

All hardware subjected to structural loading environments shall be designed to meet the requirements of MSFC HDBK-505A. For protoflight hardware, the test-load factors must be specified and supported by rationale for the values selected. MSFC approval is required prior to implementation. No load factor shall be utilized that would result in stresses beyond material yield strength. Fracture mechanics analyses shall be performed using M&P-STD-EH13-1 requirements.

8.3.11 Materials and Processes

All material and processes used in construction of the OTV shall meet the requirements of MSFC-STD-506B.

8.3.12 Control of Braze Filler

Control of braze filler material shall be in accordance with MSFC-STD-969.

8.3.13 Engineering Drawings

Engineering drawings and associated lists shall be in accordance with DoD-D-1000 and drafting practices shall be in accordance with DoD-STD-100.

8.3.14 Electrostatic Charging

a. The OTV shall be designed to accommodate or preclude buildup of electrostatic charge on any OTV surfaces.

b. The OTV shall prevent or control electrostatic discharges between the OTV and other spacecraft.

c. Electronic equipment shall be designed to withstand electrostatic discharges up to 4000 volts to the case or to any pin on external connectors. Equipment that may be damaged by electrostatic discharge between 4000 volts and 15000 volts shall be labeled warning of potential damage and special handling requirements. These voltages represent charges that may be discharged from personnel during equipment installation or maintenance. Electrostatic characteristics typically generated by personnel may be simulated by a 100 pf capacitor charged with the specified voltages and discharged through a 1500 ohm resister to the pin or case. Implementation of these requirements shall be described in the system level EMC control plan.

9.0 SYSTEM VERIFICATION

The verification program shall assure that the software and hardware conform to the stated requirements. These requirements shall be verified by assessment and/or test during the various phases of the program.

Verification methods will include assessment (similarity, analysis, inspection, validation of records, and simulation) and tests, as appropriate. In general, the method(s) selected to verify a particular requirement will be the one that provides the required assurance for the least cost. Assessment and design techniques shall be emphasized to minimize the need for testing and retesting. Testing shall be the prime method of requirements verification when any of the following conditions exist:

a. Assessment (non-test) techniques do not produce adequate results.

b. Failure modes exist which could compromise personnel safety, adversely affect STS or payload operation, or result in a significant loss of mission objectives.

c. Components are directly associated with STS, SS, or payload interfaces.

9.1 ASSESSMENT METHODS

The assessment methods includes similarity analysis, inspection, validation of records, and simulation.

9.1.1 Similarity Assessment

Verification by similarity is the process of assessing by review of prior test data or hardware configuration and applications that the article is similar or identical in design and manufacturing process to another article that has been previously been qualified to equivalent or more stringent specifications.

9.1.2 Analysis Assessment

Verification by analysis is a process used in lieu of, or in addition to, testing to verify compliance to specification requirements. The selected techniques may include systems engineering analysis, statistics and qualitative analysis, computer and hardware simulation, and analog modeling. Analysis may be used when it can be determined that all of the following apply:

a. Rigorous and accurate analysis is possible

b. Test is not effective

c. Similarity is not applicable

d. Verification by inspection is not adequate

9.1.3 Inspection Assessment

Verification by inspection is a process of physically measuring, examining, or comparing an item to the design drawings and/or schematics.

9.1.4 Validation of Records Assessment

Verification by validation of records is the process where manufacturing records are used at end-item acceptance to verify construction features and processes for flight hardware.

9.1.5 Simulation

Verification by simulation is primarily applicable to flight operations.

9.2 TEST

Verification by test is the measuring of performance parameters relative to functional, electrical, mechanical, and environmental requirements. This includes analysis of the test data as appropriate.

9.2.1 Functional Tests

Functional testing is an individual test or series of electrical of mechanical performance tests conducted on flight or flight-configured hardware and software at conditions equal to or less than design specification. Its purpose is to establish that the system performs satisfactorily in accordance with design specifications.

9.2.2 Environmental Tests

Environmental testing is an individual test or series of tests conducted on flight or flight configured hardware to assure the flight hardware will perform satisfactorily in its flight environment. Examples are vibration, acoustic, thermal, vacuum, and EMC. Environmental testing may or may not be combined with functional testing depending on the objectives of the test.

Functional testing will be accomplished before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

9.2.3 Hardware and Software Failures

Hardware and software failures during test shall disqualify all hardware and software made to the same hardware specifications and intended for the same application as the undergoing test (excluding limited life or "one-shot" items). When a failure occurs, necessary hardware or procedural or software changes shall be made and the nonconformance shall be documented and understood prior to continuing operations. The NASA concurrence shall be required for closeout of qualification or acceptance test failure dispositions.

A failure shall be defined as any condition which results in a performance parameter which is outside the required tolerance or may cause damage other than cosmetic.

The NASA shall be notified of any failure on flight or qualification hardware and software within 24 hours of the failure.

9.3 VERIFICATION PHASES

The verification activities to be accomplished in verifying that the OTV is suitable for flight and mission operations consists of development, qualification, acceptance, qualification/acceptance, crew systems verification, interfaces, prelaunch, launch, and missions, as defined in the following paragraphs.

9.3.1 Development Verification

Development verification shall be performed on selected hardware to verify the feasibility of new design approaches and provide confidence in the ability of the flight hardware to pass qualification and qualification/acceptance tests. Development verification shall be documented in the verification reports. Development test hardware should be representative of, but not necessarily identical to, flight hardware. If protoflight hardware is development tested, it shall have formal controls, plans, specifications, procedures, and reports approved by the government. The test/assessment may be designed to evaluate items such as:

a. Adequacy and optimization of design margins

b. Significant failure modes and effects

c. Safety parameters and function

d. Materials compatibility

e. Structural and dynamic stress evaluation

f. Thermal vacuum tolerance

g. Performance characteristics

9.3.2 Qualification Verification

Qualification verification shall be that which verifies that selected flight-type items meet the performance and design requirements under anticipated operational regimes and environments. Associated procedures shall be available for eliminating hazards during all mission phases. The following general rules apply to these verification tests/assessments:

a. All flight hardware shall be designed and verified to the maximum expected vibration and acoustic environments. Test duration shall be 60 seconds plus 30 seconds per mission in each axis. Random vibration criteria shall be formulated for each component installation and for each type of structure where components are to be located.

b. OTV operational environments shall be simulated as practical during conduct of tests.

c. All qualification hardware shall be representative of flight hardware and of known configuration. Any difference between the qualification and flight hardware configuration shall be documented and justified.

d. Qualification verification may be conducted on components, subassemblies, or high assemblies.

e. Life-cycle capability of moving mechanical items or items subject to high thermal cycling shall be demonstrated and/or assessment justified by analysis and documented. Consideration shall be given to all functional and environmental requirements.

f. Any failures of hardware occurring during formal qualification testing shall be a basis for test stoppage. A complete analysis must be made of a failure and corrective action documented by a nonconformance report before qualification can be restarted. Retest shall be performed to establish the adequacy of the corrective action and restore the validity of previous testing. Any unusual phenomena, occurrence, difficulty, or questionable condition occurring in the conduct of the test shall be promptly reported to the Project Manager's Office.

g. When the same hardware is scheduled for both qualification testing and flight purposes, the total life capability remaining after qualification (including retests) shall be assessed and justified as sufficient to complete all checkout and flight mission requirements.

h. Qualification tests generally should be sequential (e.g., one environment at a time) and non-destructive. Combined environments, plus functional test, may be performed when appropriate.

i. A comprehensive acceptance functional test shall be conducted prior to the first environmental test to establish a performance baseline and, at the end of the test series, for final acceptance. Abbreviated functional tests, adequate to determine environmental effects, shall be performed after each environmental test. Life and thermal vacuum environmental tests shall include functional tests.

j. Qualification verification shall be completed prior to start of OTV qualification/acceptance verification.

k. Certification of Qualification is required for each flight component.

9.3.3 Acceptance Verification

Acceptance verification shall be conducted to verify that flight hardware performs in accordance with design/manufacturing documentation. Formal controls shall be used during the testing or other activities relating to flight hardware.

The requirements for these tests/assessments which shall be completed prior to shipment of the deliverable hardware include:

a. Receiving tests/inspections

b. In-process tests/inspections at all hardware levels.

c. Joint functional validations of flight computer program and OTV via the flight computer prior to the pre-environmental functional test.

d. Pre-environmental functional test (performance, pressure/leak, interface, alignment, etc.) to establish baseline for subsequent tests.

NOTES: Pre-environmental functional tests will demonstrate that the OTV, support equipment, and software perform properly. This is a milestone to define an operational condition prior to qualification/acceptance environmental testing. All significant non-conformances from this testing and computer test software changes will be controlled during this and subsequent test periods the same as applicable test procedures.

e. Environmental tests, whenever conducted, will be as follows: dynamics test at 6 db below quality levels, thermal test limits not greater than expected in flight.

f. Pre-delivery/post-environmental verification (performance, interface, alignment, etc.).

9.3.4 Qualification/Acceptance Verification

Qualification/acceptance verification is a combination of qualification and acceptance verification performed at the component/system level on the same flight hardware/software. qualification/acceptance verification of the OTV integrated system shall be performed to verify that the flight hardware, flight software, and support equipment meet the design and performance requirements under anticipated operational regimes and environments.

Qualification/acceptance verification is subject to the same requirements and controls specified in paragraphs 9.2.2 and 9.2.3 with the addition of the following: (a) space thermal vacuum test; and (b) OTV environmental test levels shall be established so as not to exceed the levels to which the components have been qualified.

9.3.5 Prelaunch Verification

Prelaunch verification is that part of launch operations which begins with the OTV arrival at the launch site and terminates with beginning of the final countdown.

Prelaunch verification shall be performed to verify that the OTV systems are in readiness for the mission. All planned flight equipment/test/checkout activities shall be minimized, shall be at the systems level, and shall be oriented toward verifying the continued integrity of the hardware.

This effort includes post-flight evaluation and checkout of the OTV. Hardware failing to meet post-flight acceptance criteria shall be identified for refurbishment. Upon completion of the refurbishment cycle, the OTV shall be subject to prelaunch verification.

Prelaunch verification shall include but not be limited to the following verification activities:

a. Receiving inspection for damage during shipment including review of the shipping environment data.

b. Abbreviated OTV system test including practice count (dry run) extending through payload separation.

c. Interface and electrical tests.

d. Space vehicle combined systems test including practice count (dry run) extending through payload separation.

e. Space vehicle combined system RFI test.

f. Any special tests necessary to verify adequacy of installation or operations performed at the site.

9.3.6 Launch Verification

The launch verification phase begins with the final countdown of the STS and ends with the STS launch. The contractor shall provide real-time monitoring of pertinent parameters and furnish them to the STS as criteria for launch inhibit if mission or safety critical parameters are identified.

9.3.7 OTV/Orbiter/Space Station/Mission Verification

The OTV-Orbiter/Space Station flight/mission verification phase begins prior to OTV separation from the Orbiter/SS and ends with post-separation checkout of the OTV. Flight/mission verification shall verify activation and checkout of the OTV and operational systems compatibility between the OTV, TDRSS, ground networks, and the OTV OSC/SSCS. Prior to separation from the Orbiter/SS the OTV systems flight readiness shall be verified by hardline/RF

interface. After the OTV flight/mission and prior to docking with the Orbiter/SS the OTV systems status shall be verifiable to the Orbiter/SS through an RF command and data link between the OTV and Orbiter/SS.

9.3.8 STS Crew Systems Verification

STS crew systems verification consists of all activities required to assure OTV will perform in accordance with all operational and hardware requirements. A Crew System Verification Plan shall be prepared in accordance with JSC-14096, Training Annex Data Requirements. Crew training will address all nominal and unplanned contingency operations required of the crew.

9.3.9 Interface Verification

9.3.9.1 OTV to STS Interface

The OTV to STS interfaces as defined in the STS/OTV Unique Interface Control document shall be verified prior to integrated operations with the STS. The STS/OTV integrated interface verification operations shall be in accordance with JSC-14046A.

9.3.9.2 OTV to Payload Interface

The OTV to payload physcial and functional interfaces as defined in the OTV/Payload Interface Control Document shall be verified prior to integrated operations with the payload and/or STS.

9.3.9.3 OTV to SS Interface

The OTV to SS interfaces as defined in SS-IRD-500, the SS/OTV Interface Requirements, shall be verified prior to integrated operations with the SS.

9.4 SAFETY VERIFICATION

The safety verification activities shall include those test, analyses, and inspections identified by the safety assessment reviews as necessary to assure the proper control of OTV hazards.

9.5 SOFTWARE VERIFICATION AND VALIDATION

Software verification and validation shall be in accordance with MSFC-MA-001-006-2H. Procedures shall be generated and implemented to exercise the flight software to the extent necessary to satisfy all OTV system hardware/software requirements.

9.6 VERIFICATION CROSS-REFERENCE INDEX

A verification cross-reference will be completed to indicate how each requirement is verified and which requirement will apply to each verification phase.

10.0 LOGISTICS

A logistics program for all OTV deliverable hardware will be prepared to support all levels of operation and maintenance, spares inventorying, personnel training, and transportation. OTV logistics and maintenance support

equipment will be compatible with the STS and ground facilities and will be designed to maximize accommodations for other payloads. The OTV logistics plan shall encompass maintenance engineering analysis, spare identification, personnel training and transportation requirements.

10.1 SPARES

Maintenance Engineering Analysis (MEA) shall be conducted to identify the assemblies, subassemblies, components, parts, and/or repair kits required as replacement of like items during test, operations, maintenance, and repair of OTV ground and flight hardware.

Components subassemblies, assemblies, and parts identified by the MEA shall be recorded and tracked through provisioning to the point of delivery. Replacement items shall be available at sites based on the MEA.

10.1.1 Orbital Replacement Units (ORUs)

The MEA shall identify the ORUs for SS application, and recommended ORU spares to be carried onboard the SS.

10.1.2 ORU Carriers

ORU carriers for the SS logistics module shall be provided by the SS. The OTV project will provide requirements.

10.2 FACILITIES AND FACILITY EQUIPMENT

Existing and modified facilities shall be utilized to the extent practicable.

10.3 PACKAGING, HANDLING, AND TRANSPORTATION

Packaging, handling, and transportation of the OTV after assembly to and from the launch site shall meet the requirements of NHB 6000.1C and MSFC-STD-126. Packaging, handling, and transportation of the OTV after assembly to and from the launch site shall meet the requirements of NHB 6000.1C and MSFC-STD-26E. Packaging, handling and transportation sheets (NASA Form 1426 or equivalent) shall be prepared to depict the requirements for packaging, handling and shipping the OTV.

11.0 CONFIGURATION MANAGEMENT

The contractor will be required to have a Configuration Management System which complies with MMI 8040.15, MM 8040.12 (Ref. DoD STD-100 Drawing Spec.), MM 8040.13, and MM 8040.5.

12.0 OTHER DATA

12.1 DEFINITIONS

For the purpose of interpretation of this specification, the following definitions will apply.

a) Limit Load - The maximum load expected on the structure during its service life, including: pressure, thermally induced loads and applicable external loads.

b) Ultimate Factor of Safety (FS) - The factor by which the limit load is multiplied to obtain the ultimate load.

c) Design Thickness - Stress calculations of structural members that are critical for stability shall use the mean drawing thickness or 1.05 times the minimum drawing thickness (whichever is less). Structural members that are critical for strength shall use the mean drawing thickness or 1.10 times the minimum drawing thickness (whichever is less). The wall thickness in stress calculations for pressure vessels will be the minimum wall thickness shown on the pressure vessel drawing.

d) Ultimate Load - The product of the limit load multiplied by the ultimate FS. This is the maximum load that the structure must withstand without failure.

e) Allowable Load - The maximum load to which a particular element can be subjected without failure.

f) Maximum Operating Pressure - The maximum gage pressure attainable under normal operating conditions at any given point within the pressure system. This is a combined pressure of maximum regulated ullage pressure plus fluidhead, including acceleration and thermal effects on the fluid.

g) Proof Pressure - The pressure to which production pressure vessels are subjected:

   1) To fulfill the acceptance requirement to give evidence of satisfactory workmanship and material quality; and/or
   2) To establish the maximum undetected flaw size in the pressure vessel.

   Proof pressure is the product of limit pressure and the proof factor at test temperature. There shall be no detrimental yielding at proof pressure.

h) Standby Status - Ready for launch (except for main propellant fill, crew ingress and final system verification).

i) Critical Function - A function which if lost would cause loss of personnel or the flight vehicle.

j) Fail-Safe - The ability to sustain a failure and retain the capability to successfully terminate the mission.

k) Fail-Operational - The ability to sustain a failure and retain full operation capability for safe mission continuation.

l) Interfaces - When the term "interfaces" (I/F) is used in this specification, it shall be in the following context:

   1) Those physical I/Fs of OTV contractor-designed and developed hardware with hardware designed and developed by an associate contractor (e.g., the "work to" I/F, [Ref. TBD]), and
   2) Those design requirements/constraints that are imposed on the OTV contractor at the physical I/F with associate contractor designed and developed hardware.

m) Maximum Relief Ullage Pressure - The highest ullage pressure achieved during a relief mode including transient overshoots.

n) Limit Pressure

   1) Maximum Normal Operating Differential Pressure (including transient pressure) - occuring in hydraulic and pneumatic systems, tanks, high pressure vessels, actuating cylinders, valves, filters, switches, lines and fittings not otherwise specified.

2) Maximum Differential Pressure - The maximum pressure attainable at any given point within the pressure system (i.e., LO_2 and LH_2 tanks, propellant feedlines and recirculation line). It is a combined pressure of maximum regulated ullage pressure plus fluidhead, including acceleration and thermal effects on the fluid and transient pressure.

3) Minimum Operating Pressure - The minimum pressure under normal operating conditions at any given point within the pressure system. This is a combined pressure of minimum regulated ullage pressure plus fluid head including acceleration and thermal effects on the fluid.

4) Minimum Regulated Ullage Pressure - Minimum ullage pressure achieved during normal pressurized operations, including transient overshoots.

o) Fracture Critical Weld - A weld is "fracture critical" when a fracture mechanics analysis of the weld indicates that the critical flaw depth (at $a/2c = 0.15$) at proof test load is less than the thickness of the weld land. This definition only applies to LO_2 and LH_2 tank welds.

p) Transient Pressure - Time-dependent pressure in which the characteristic time of fluctuation is comparable to significant dynamic time constants of the structure and vehicle systems, e.g., pressure fluctuation caused by the opening/closing of valves, pump surges, flutter of check or relief valves, engine thrust transients, engine gimballing and liquid sloshing.

q) Well Defined Loads - The thrust, inertia from thrust, dead weight, and that part of pressure loads due to ullage and inertia from thrust.

r) Life Factor - A function of the number of pressure cycles incurred over 60% of proof pressure for the life of the vehicle multiplied by a scatter factor of 4.

s) Fracture Toughness Ratio (FTR) - The ratio of material toughness at use or design temperature divided by the material toughness at proof temperature.

t) Proof Factor - Life Factors divided by Fracture Toughness Ratio

12.2 ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations are used in the text of this document and are listed here for convenience:

AFD	Aft Flight Deck
AFSCF	Air Force Satellite Control Facility
ASE	Airborne Support Equipment
AXAF	Advanced X-ray Astrophyscis Facility
BER	Bit Error Ratio
C&DM	Communication and Data Management
CEI	Contract End Items
CIL	Critical Items List
CG	Center of Gravity
CMA	Configuration Management Accounting
COFW	Certificate of Flight Worthiness
CRT	Cathode Ray Tube
CY	Calendar Year
DDT&E	Design, Development, Test, and Evaluation
DMS	Data Management System
DOF	Degree of Freedom
DOS	Disk Operating System
DPA	Destructive Physical Analysis
DPD	Data Procurement Document
DR	Data Requirements
DRM	Design Reference Mission
ECP	Engineering Change Proposal
EEE	Electrical, Electronic, and Electromechanical
EGSE	Electrical Ground Support Equipment
ELS	Eastern Launch Site
EMC	Electromagnetic Compatibility
EPS	Electrical Power Subsystem
EVA	Extra Vehicular Activity
FMEA	Failure Mode Effects Analysis
FS	Factor of Safety
FTR	Fracture Toughness Ratio
FY	Fiscal Year
GCC	Ground Control Console
GEO	Geosynchronous Earth Orbit
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GN&C	Guidance, Navigation and Control
GSE	Ground Support Equipment
GSTDN	Ground Spaceflight Tracking and Data Network
GSFC	Goddard Space Flight Center
HOL	
IBM	International Business Machines
ICD	Interface Control Document
IOC	Initial Operational Capability
IPCL	Instrumentation Program and Command List
IRD	Interface Requirements Document
JSC	Johnson Space Center
KSC	Kennedy Space Center
KOPS	Thousands of Operations per second
LEO	Low Earth Orbit
LVLH	Local Vertical Local Horizontal
MEA	Maintenance Engineering Analysis

MCC	Mission Control Center
MGMT	Management
MGSE	Mechanical Ground S????? Equipment
MLI	Multi-Layer Insulation
MMI	Marshall Management Instruction
MMS	Multi-Mission Spacecraft
MRMS	Mobile Remote Manipulator System
MSFC	Marshall Space Flight Center
NHB	NASA Handbook
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications
nmi	Nautical Mile
NORAD	North American Air Defense Command
NSPAR	Nonstandard Parts Approval Request
NSTS	National Space Transportation System
OAE	Orbital Adjust Engines
OMV	Orbital Maneuvering Vehicle
OPS	Operations
ORI	Operational Readiness Inspections
ORU	Orbital Replacement Unit
OSC	Operations Support Center
OSF	Office of Space Flight
OSSA	Office of Space Science and Applications
OTV	Orbit Transfer Vehicle
PC	Personal Computer
PDR	Preliminary Design Review
PIND	Particle Impact Noise Detection
PIP	Payload Integration Plan
PMS	Propellant Management System
POCC	Payload Operations Control Center
PRS	Payload Retention System
RCS	Reaction Control System
RF	Radio Frequency
RFI	Radio Frequency Interference
RMS	Remote Manipulator System
SCIT	Standard Change Integration and Tracking
SE&I	Systems Engineering and Integration
SGLS	Space Ground Link System
SIM	Simulation
SOW	Statement of Work
SS	Space Station
SSCS	Space Station Control Station
SSSE	Space Station Support Equipment
STAR	Shuttle Turnaround Assessment Report
STDN	Spaceflight Tracking and Data Network
STS	Space Transportation System
TBD	To be determined
TBR	To be revised
TCRSD	Test and Checkout Requirements Specification Document
TCS	Thermal Control Subsystem
TDRSS	Tracking and Data Relay Satellite System
TOS	Transfer Orbit Stage
TPI	Terminal Phase Initiation
UST	Universal Standard Time
VAFB	Vandenberg Air Force Base
VMS	Velocity Measuring System
VSTAR	Vandenberg Shuttle Turnaround Assessment Report
WBS	Work Breakdown Structure
WLS	Western Launch Site